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Investigation of Consumer Attitudes Towards Emerging Novel Food Processing Technologies in the Republic of Ireland

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Investigation of Consumer Attitudes Towards Emerging Novel Food Processing Technologies in Republic of Ireland

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Abstract

Food industry and governmental organisations are continuously working on innovative food processing technologies in order to produce safe foods without causing undesirable changes in the food products. Food is a very sensitive area so consumers are conservative in accepting food products produced from novel technologies compared to other products. Food is basic needs of humans and it is becoming more and more globalized recently, but public perceptions are not same in different countries. The aim of this research was to investigate consumer attitudes toward novel food processing technologies in Republic of Ireland. A quantitative research was conducted and data was collected by using a questionnaire as a research instrument. The collected data was analysed by using SPSS (Statistical Package for the Social Sciences) Version 26. Five novel food processing technologies selected in this study as; Genetically Modified Organisms (GMO), Irradiation, Nanotechnology, Thermal Emerging Novel Food Processing Technologies (Radio Frequency Heating and Ohmic Heating) and Non-Thermal Emerging Novel Food Processing Technologies (Pulsed Electric Field, Ultrasound, High Pressure Processing). Level of awareness and perception of risks and benefits with respect to these technologies are investigated.

Three clusters were identified as; technological enthusiasts (17.7%), technological neutrals (46.6%) and technological sceptics (35.7%). It is found that public trust in Irish governmental organisations, EU Regulatory bodies and academic/health professionals are significantly related to the acceptance of emerging novel food processing technologies.

Declaration

I hereby certify that this material, which I now submit in part fulfilment of the requirement for the award of MSc in Food Safety Management, is entirely my own work and has not been taken from the work of others save and to the extent such work has been cited and acknowledged within the text of my work.

This thesis was prepared according to the guidelines for dissertation production in the M.Sc. Food Safety Management and has not been submitted in whole or in part for an award in any other Institute or University.

The work reported on in this thesis conforms to the principles and requirements of the Institute's guidelines for ethics in research.

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Signed _____

Candidate

Date _____

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List of Abbreviations

Abbreviation	Details
EU	European Union
FSAI	Food Safety Authority Ireland
GMO	Genetically Modified Organisms
Gy	Gray
HHP	High Pressure Processing
OH	Ohmic Heating
PEF	Pulsed Electric Field
RF	Radiofrequency
SPSS	Statistical Package for the Social Sciences
Teagasc	The Agriculture and Food Development Authority Ireland
WHO	World Health Organisation

Chapter 1. Introduction

1.1 Overview

Food is the basic need of humans and the main economic driver of the European Union (EU) (Galanakis, 2016). Food sector is consisting of many subsectors and growing rapidly. The global food retail market alone was estimated to be worth $5.8 trillion annually in 2014 (Marketline 2015, cited in Chaudhry 2017, p5). Like any other sector, food industry is also driven by innovation, competitiveness and profitability.

Through the decades, food have been processed in varied ways like; heat treatment, fermentation, curing, smoking, drying etc. to kill pests and pathogens, to enhance nutritional value, taste, flavour and texture and to increase shelf life. The food manufacturers and governmental agencies are continuously working on innovative food processing technologies to provide safe and nutritious foods for the customers (Tokusoglu and Swanson, 2015). The aim is to develop food processing technologies that keep desirable sensory qualities and reduce undesirable changes in food because of the processing (Sun, 2005). Traditional processing methods like pasteurisation and sterilisation are also used to produce safe products by eliminating microorganisms but these processes can change natural taste and flavour of the food and also, they can destroy vitamins (Sun, 2005).

Food production is becoming more and more globalized, on the other hand public perceptions of quality and safety of foods are not same in different countries. For example, even in European Union (EU), consumer priorities and perceptions differ from country to country, some countries putting pesticides and animal welfare on the top of the priority list, while others think that genetically modified organisms are more worrying (Chaudhry, 2017).

Food is a very sensitive area, so consumers are particularly conservative while accepting and perceiving foods compared to other products. A new technological processing method must get away various societal and regulatory barriers before commercially applied (Chaudhry, 2017). Building consumer confidence and trust is very important since it determines failure or success of the novel food processing technology in the market. Acceptance or rejection of these technologies by consumers is a consequence of a complex decision process that involves evaluating the risks and benefits associated with the new technologies and existing alternatives (Henson 1995, cited in Galanakis 2016, p78).

To prevent rejection by the consumers, it is important to include consumer aspects in an early stage of research and development. There are two main questions to be answered at this early period;

- Which are the relevant perceptions of consumers in the context of food innovations and how they combine toward the final response,
- The products in which novel processing is applied (Gupta et al, 2012, Ronteltap et al, 2012, cited in Galanakis 2016, p271).

Having reviewed the literature carefully, a lack of resources on perception of consumers on novel food technologies in Republic of Ireland is observed. Teagasc (agriculture and food development authority) published a report in 2013 on Irish consumer and industry acceptance of novel food technologies. This study conducted quantitative analysis for nanotechnology applications in food processing. Conducting qualitative analysis on other innovative technologies with 47 consumers in 2011, Teagasc report provided a better understanding of consumer and industry perceptions but a more generalized and updated analysis more focusing on the consumers would be useful on this topic in the country.

There was a lack of literature on segments regarding the application of novel technologies and trust-acceptance relations in Ireland. Therefore, this study will contribute to the literature accordingly.

1.2 Research Objectives

The main aim of this study is to investigate consumer attitudes towards emerging novel food technologies in Republic of Ireland.

In order to fulfil this aim, 4 objectives are defined as follows:

1. To investigate consumers awareness on novel food technologies;
2. To define the similarities among the consumers perceptions by making cluster analysis;
3. To find out risk-benefit perceptions of the consumers on novel food processing technologies;
4. To investigate whether trust and confidence to several organisations affect acceptance of novel food technology by the consumers.

1.3 Organisation of the Dissertation

This study is divided into 5 Chapters:

Chapter 1- Introduction: This section is a brief introduction of the research topic, also includes the aim of the research and objectives.

Chapter 2- Literature Review: Previous literature on novel food processing technologies and consumer science reviewed.

Chapter 3- Research Methodology: This section includes information about how the research is conducted. The questionnaire design, data collection and data analysis methods are also discussed in detail.

Chapter 4- Results and Discussion: The demographic profile of the respondents, the findings of the questionnaire and the statistical analysis of the data presented by using IBM SPSS Version 26 software package. Discussion paragraphs are included after presenting the main results.

Chapter 5- Conclusion, Recommendations and Limitations: In this section the findings of the study is summarised and suggestions for future studies are included. Limitations of this research are also explained in this chapter.

Chapter 2. Literature Review

2.1 An overview of emerging novel food processing technologies

5 technologies are selected by analysing factors such as; their level of usage in food industry, novelty and possible future developments. Although GMO and Irradiation are not very new technologies; they were also selected in order to examine the possible change of perceptions of consumers over time towards these technologies.

The following 5 technologies are selected in this study;

1- Genetically Modified Organisms (GMO);
2- Food Irradiation;
3- Nanotechnology;
4- Thermal Emerging Food-Processing Technologies (Radio Frequency Heating and Ohmic Heating);
5- Non-Thermal Emerging Food-Processing Technologies (PEF, Ultrasound, HHP).

Each of these technologies explained in detail in this section.

2.1.1 Genetically Modified Organism (GMO)

Biotechnology is being used to produce genetically modified organisms (GMOs) that are used in food production. The technology is often called “modern biotechnology” or “gene technology”, “recombinant DNA technology” or “genetic engineering”. WHO (2014) defined GMOs as organisms in which the genetic material (DNA) has been altered in a way that does not occur naturally. Selected individual genes can be transferred from one organism into another. Genes can be transferred across unrelated species, like; from plant to an animal or from a microorganism to a plant (Mahgoub, 2016).

Foods produced from or using GM organisms are defined as GM foods.GM has been used different ways to assist food production to improve factors like storage or nutritional value

of food. Many processed foods in the world contain GM ingredients. In EU, GMO usage in food production regulated by the GM Food and Feed Regulation (EC No. 1829/2003). Food ingredients and additives from five types of GM crops can be found in EU market (FSAI, 2019);

- Soya bean (pest resistant / herbicide tolerant / modified fatty acid profile) – Food and food additives,
- Maize (pest resistant / herbicide tolerant / drought tolerance) – Food and food additives,
- Oilseed rape (herbicide tolerant) – Food and food additives,
- Cotton (pest resistant / herbicide tolerant) – Food and food additives,
- Sugar beet (herbicide tolerant) – Food

According to Spetsidis and Schamel (2002), genomics is the key technological driver behind the latest technological developments. These developments inevitably will give rise radical changes in food production processes in the future. Recently, functional foods are studied intensively by using genetic modification. Isolating particular genes coding for enzymes and introduce them into microorganisms that are used in food production (e.g. chymosin derived from bacteria *K.lactis*), is now possible (Spetsidis and Schamel, 2002). It is estimated that 50% of all industrial enzymes have already been genetically modified (Roller and Goodenough, 1998, cited in Spetsidis and Schamel, 2002). Gene technology is turned to be of great importance for food production so in this study consumer approach towards GMO is also included.

2.1.2 Irradiated Foods

Food irradiation has been described as the "most extensively studied food processing technology in the history of humankind" but it is still considered a relatively "new" technology (Sommers, 2006). In irradiation, food is exposed to a specific dose of ionizing radiation. Irradiation of food can control insect infestation, reduce the number of pathogenic and spoilage microorganisms and delay or eliminate ripening, germination or sprouting fresh food (Arvanitoyannis, 2010). In industry it is applied in specific preserved areas either in batch or continuous operation. The source of irradiation can be; gamma rays, electron beams and X-rays.

The dose of radiation is measured in the SI unit known as Gray (Gy). One Gray (Gy) dose of radiation is equal to 1 joule of energy absorbed per kg of food material. In radiation processing of foods, the doses are generally measured in kGy (1,000 Gy). Radiation application of foods divided into three main categories according to dose of application (Elkins, 2012).

- Low Dose Applications (up to 1 kGy)
    - Sprout inhibition in bulbs and tubers 0.03-0.15 kGy
    - Delay in fruit ripening 0.25-0.75 kGy
    - Insect disinfestation including quarantine treatment and elimination of food borne parasites 0.07-1.00 kGy
- Medium Dose Applications (1 kGy to 10 kGy)
    - Reduction of spoilage microbes to prolong shelf-life of meat, poultry and seafoods under refrigeration 1.50–3.00 kGy
    - Reduction of pathogenic microbes in fresh and frozen meat, poultry and seafoods 3.00–7.00 kGy

- Reducing the number of microorganisms in spices to improve hygienic quality 10.00 kGy

- High Dose Applications (above 10 kGy)
  - Sterilization of packaged meat, poultry, and their products that are shelf stable without refrigeration 25.00-70.00 kGy
  - Sterilization of Hospital diets 25.00-70.00 kGy
  - Product improvement as increased juice yield or improved re-hydration

2.1.3 Nanotechnology

Nanotechnology researches on food processing have been rapidly growing in the last decade and it is an emerging processing and packaging method. Nanotechnology researches includes application of very small particles (1-100 nm). Nanotubes, fulleneres, nanofibers, nanocylinders, nanosheets, and self-assembled nanostructures, polymer nanocomposites are the nanostructures that are under research in food industry (Anandharamakrishnan, 2019). The main focus in nanotechnology applications in food sector involves; food packaging, smart labels, nanosized ingredients and additives, and nanoscale carriers for the delivery of nutrients and supplements (Chaudhry, 2017). Figure 2.1 below summarises food nanotechnology applications.

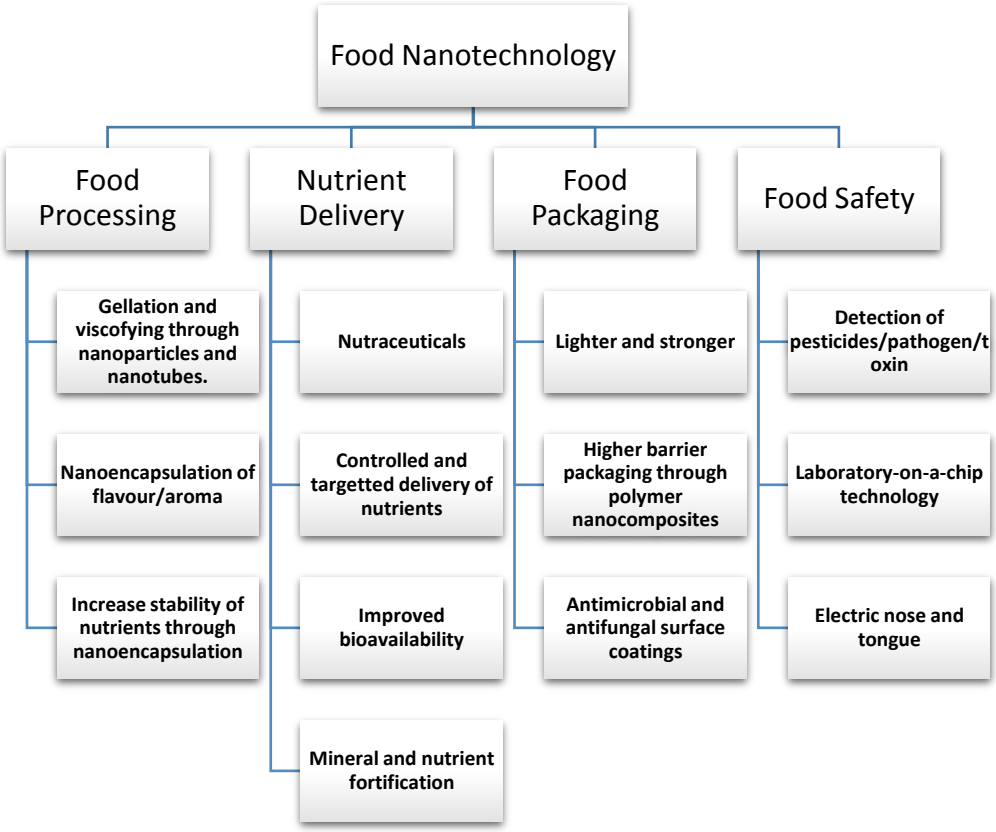

Figure 2.1 Application of nanotechnology in food (Source: Anandharamakrishnan, 2019).

It is stated that the nanomaterials used in food applications consists of inorganic, organic and hybrid materials, examples are; metals (iron, silver), metal oxides (titanium dioxide), the alkaline earth metals (calcium and magnesium), non-metals (selenium, silicates), organic materials (wide range of vitamins, antioxidants, colours, flavours, preservatives) and hybrid of non-functionalized nanomaterials (with enzymes or binding moieties attached to the surface) (Chaudhry, 2017). Titanium dioxide (TiO_2, E171) and silica (SiO_2, E551) are approved additives that are known to contain nanoscale particles (Chaudhry, 2017).

Safety evaluation of nanoparticles in food must be completed and various risks should be evaluated before commercialization (Anandharamakrishnan, 2019). In literature there are various researches on toxicity of nanomaterials. One of the nanoparticles that is used in food products (wine and beer for clarification) is slica nanoparticles (Dekkers et al., 2013, cited in Anandharamakrishnan, 2019). Ye et al. (2010) studied toxicity by exposing rats' myocardial cells to slica nanoparticles with different dosage, size and time of exposure. Results of this study showed that slica nanoparticles have toxic effects and can cause cell injuries. It is also found that the toxicity level depends on size and dosage of the slica-nanoparticles.

Nanotechnology also has importance on food packaging. In recent years European Union has started promoting the usage of bio-based biopolymers in order to reduce plastic waste. Biopolymers are degradable materials based on plant and animal origin (starch, cellulose, chitosan) (Anandharamakrishnan, 2019). Nanotechnology is an emerging field so it has many challenges and uncertain risks. Development of risk assessment methods is necessary to control safety and health issues on applications of nanotechnology in food processing.

2.1.4 Thermal (Radio Frequency Heating and Ohmic Heating) Emerging Food-Processing Technologies

Radio Frequency Heating and Ohmic Heating are advanced thermal food processing methods.

2.1.4.1 Radio Frequency Heating

Radio Frequency is electromagnetic waves. Heat is generated by molecular friction in high frequency electric fields (Awuah, 2015). Awuah (2015) stated that RF is mainly applied to dielectric materials due to their poor electrical-conduction characteristics and most food products can be defined as dielectric materials. It would take longer time to heat dielectric materials by applying heat source (conventional heating) outside the product (Awuah, 2015). RF make this process much faster than any conventional heating method, it is also volumetric. In RF heating, electrical energy is directly converted to heat, this energy conversion happens in food itself and heat is absorbed by the food (Rowley 2001, cited by Awuah 2015, p191).

For RF applications; frequencies of 13.56, 27.12, and 40.68 are allowed to use in United States in industrial applications (Piyasena 2003, cited in Tewari, 2007). In food processing, RF has been applied to drying, baking, and thawing of frozen meat (Richardson 2001, cited by Awuah 2015, p3).RF heating also found to be useful in pasteurisation of different food products such as; milk, meat products, fruit juice and spices (Jaiswal, 2017). Kim et al. (2012) investigated RF heating in the process of black and red pepper spice. It is found that RF achieved 5-log reduction of *Salmonella Typhimurium* and *Escherichia Coli O157:H7* without affecting the color quality change of black and red peppers. Naidu et al. (2012) studied effects of different drying methods on the colour of fenugreek and on its

constituents. Hot air (HA, 40^{o}C, 58-63% RH), low humidity air (LHA, 40 ^{o}C, 28-30% RH), and radiofrequency (RF, 40^{o}C, 56-60% RH)were investigated for drying of fenugreek greens. The results of this study showed that β-carotene retention was higher in in LHA (63.7%), than RF followed (17.56%) and it was lower in HA (14.2%).When compared with HA drying (450 min), required time for drying was shorter in LHA and RF (330 min).

Palazoglu et all. (2012) investigated effect of RF heating on acrylamide content, texture, and colour of partially baked cookies. Cookies partially baked for 8 and 9 min were post dried in a 27.12 MHz RF tunnel oven. The result of acrylamide level was lower in RF post drying cookies (74.6 ng/g for partially baked cookies for 9 min, 51.1 ng/g for partially baked cookies for 8 min). The acrylamide level was 107.3 ng/g for control cookies (baked in conventional oven at 205 oC for 11 min). RF post dried cookies observed to have lower degree of browning. RF is a faster heating process when compared with conventional methods. It has higher penetration depth and more uniform heating (Jaiswal. 2017)

2.1.4.2 Ohmic Heating

In ohmic heating the food is placed between two electrodes and an alternating electric current is passed through the circuit causing generation of heat in the food matrix uniformly and volumetrically (Ahmed et all, 2010). Ohmic heating directly converts electrical energy to heat. This system is similar with electric circuit that composed of a resistance and a source of voltage and current, in ohmic heating, the food is acting as a resistance when placed between two electrodes (Ahmed et all, 2010).

Compared with the conventional methods the main advantages of ohmic heating are; rapid heating, avoiding hot surfaces and minimalize temperature gradients (Jaeger et all, 2016). Electrical conductivity is very important parameter in application of ohmic heating in food products. Ahmed et all (2010) stated that, electrical conductivity is depends on the temperature and there is a linear relation between electrical conductivity and temperature. Electrical conductivity of ginger paste found to be increasing with temperature (Kautkar et all, 2015).

Application of ohmic heating in food processing has been investigated in the literature.Ohmic heating technique has been successfully applied for liquid food products like; orange and tomato juices, soymilk and milk (Ahmed et al, 2010). Successful applications have been made in the processing of acidic fruit juices. The rapidity and simplicity of the method make it proper for aseptic food processing (Ahmed et al, 2010). It has a positive pasteurization effect on food-borne pathogens due to low pH, thermal treatment, and the electric effect (Kulcu and Gurbuz, 2018).

Kulcu and Gurbuz (2018) applied ohmic heating on thawing of meat (beef) and they compared the results with other two thawing methods; dissolved meat at room temperature (20±2 ^{o}C) and dissolved meat in a refrigerator.In this study changes in colour and

microbiological count examined and it is found that ohmic heating system can be used in thawing frozen meat; decreasing thawing time, nutritional losses and weight losses.

Effectiveness of ohmic heating on semi-cooked meat balls examined and high cooking yield, moisture retention and fat retention values were observed whereas it is also found that; it was not effective to eliminate *L. monocytogenes* that are found in meat ball samples (Sengun et al, 2014). The main advantage of ohmic heating technology is its energy efficiency, which is in the order of 90% and above (Nguyen et al, 2013, cited in Galanakis, 2016). A small amount of heat is lost from the heating chamber. In a study conducted at Agri-Food Canada's Food Research and Development Centre (FRDC), the traditional smokehouse cooking was replaced by ohmic heating technology and energy saving was at least 70% (Vicente et al, 2006, cited in Galanakis, 2016). Ohmic heating is an effective and promising technology but future studies are needed on application of combined cooking methods with ohmic heating for different foods.

2.1.5 Non-Thermal Emerging Food-Processing Technologies

Nonthermal food-processing technologies are comprehensive involving; Pulsed Electric Field (PEF), Ultrasound and High Pressure Processing (HPP). In addition pulsed x-rays, pulsed high intensity light, magnetic fields, plasma, ozone and electrolyzed water are also other non-thermal processing methods that are taking attention of the industry (Tokusoglu and Swanson, 2015). Minimal temperature rise during non-thermal processing allows better retention of bioactive compounds (Villamiel et al., 2017). In this research main focus is on PEF, Ultrasound and HHP.

2.1.5.1 Pulsed Electric Field (PEF)

PEF is mostly used in food products that are containing heat sensitive constituents like whey proteins, immunoglobulins and vitamins (Tewari, 2007). The most important advantages of PEF applications in food industry are; protection of color, flavor, texture, nutritional value of the food and lower operational costs (Tewari, 2007).

In PEF processing, fluid foods are exposed to microsecond burst of high-intensity electric fields; 10-100 kV/cm (Tokusoglu and Swanson, 2015). This inactivates selected microorganisms by disturbing cell membranes. Tokusoglu and Swanson, 2015, stated that PEF processing provides pathogen inactivation, shelf life extension of liquid foods, unwanted enzyme inactivation, improves functionality and texture of foods, gives innovative fresh liquid foods and reduced solid volume (sludge) of wastewater (see Figure 2.2 below).

Figure 2.2 The usage area of PEF
(Source: Tokusoglu and Swanson, 2015)

In 2006, U.S. Food and Drug Administration (FDA) approved the first commercial application of PEF for processing of fruit juices (Jaiswal, 2017). The company (Genesis Juice Corporation-Eugene, OR, USA) cited motivations were; the avoidance of loss of flavor, and the shelf life increase up to 4 weeks (Galanakis, 2016). However, it is reported that the company afterwards switched from PEF to HHP for undisclosed reasons (Sampedro et al, 2014, cited in Galanakis, 2016). In recent years new market opportunities have enlarged the commercially available foods processed by PEF technology like apple juice, apple-strawberry juice, carrot juice, carrot-celery-beet juice, herbal tonic, strawberry lemonade and ginger lemonade in USA (Galanakis, 2016).

A successful transfer of PEF processing conditions from lab to industrial scale has been achieved but this system still demonstrate some limitations in food processing area (Galanakis, 2016). Food products with large electrical conductivity are not suitable for PEF processing because the peak electric field across the chamber is reduced; as the

conductivity rises, the lethality (for microorganisms) of the process decreases (Galanakis, 2016). Another limitation is the presence of particulates in the liquid because high-energy inputs may be needed to inactivate microorganisms and there is a risk of dielectric breakdown of food (Brennan 2012, cited in Galanakis, 2016). Therefore, PEF processing systems are still under development, since there is still a need for optimization of PEF process equipment for industrial use (Jaiswal, 2017). It is important to determine not only the optimal conditions to produce safe and fresh-like products but also to carefully determine food products that are most suitable for PEF processing (Galanakis, 2016).

2.1.5.2 Ultrasound

Ultrasound waves are very short waves (wavelengths in the range of centimetres to nanometers), generally produced by technological sources (Villamielet al, 2017).

In food processing, the effectiveness of ultrasound depend on the following parameters; frequency and amplitude of ultrasonic waves, hydrostatic pressure and temperature (Canovas et al, 2005). Ultrasound ranges divided into high-frequency, low-energy, diagnostic ultrasound in the MHz range and low-frequency, high-energy, power ultrasound in the kHz range (Jaiswal. 2017). The most common applications of ultrasound processing in food industry include crystallization, degassing, drying, extraction, filtration, freezing, homogenization, meat tenderization, sterilisation and microbial activation (Villamiel et al, 2017). Table 2.1 below summarises the main usage of power ultrasound in food processing (Zeuthen, 2003).

Table 2.1 Usage of Power Ultrasound in Food Processing

Mechanical effects	Chemical and biochemical effects
Accelerated freezing	Accelerated oxidation and ageing
Crystallisation of fats, sugars, etc	Alteration of enzyme activity
Degassing	Bacterial action
Destruction of foams	Effluent treatment
Extraction of flavourings	Modification of growth of living cells
Filtration and drying	Sterilisation of equipment
Mixing and homogenization	
Precipitation of airborne powders	
Ultrasonic cutting	

(Source: Zeuthen, 2003)

There is comprehensive literature on the effects of ultrasound in different food processing applications. The most recent researches are focusing on application of ultrasound to extraction of anthocyanin from natural sources. Anthocyanin is a pigment that have a characteristics of colouration to many fruits, vegetables and flowers (Villamiel et al, 2017). It is considered that anthocyanin has a potential to replace synthetic food colorants (E163) (Haminiuk et al. 2012, cited inVillamiel et al. 2017). Marquez et al. (2013) studied ultrasound-assisted extraction of phenolic compounds from Laurus nobilis L. (Laureceae). The results of this study showed that ultrasound assisted extraction is an effective and reliable method in extracting phenolic compounds from vegetables.

Ultrasound is also an emerging technology that can be used to inactivate microorganisms (Jaiswal, 2017). Commonly studied microorganisms in the field of ultrasound are, *Saccharomyces cerevisiae* and *Escherichia coli* like other methods of food preservation (Zeuthen, 2003). The inactivation of these microorganisms has been proven in the application of ultrasonic waves (Zeuthen, 2003).

The efficiency of inactivation approaches to 100% at laboratory scale but in industrial food processing less control of critical factors would prevent inactivation efficiencies from reaching such high levels (FDA 2015, cited in Galanakis, 2016). Therefore, ultrasound has been under research on lab scale because of the difficulty to scale up the ultrasound equipment to industry size with the same working conditions (Jaiswal, 2017). Although there are limitations that decrease the development in industrial scale, combination of ultrasound with other preservation processes, like heat (thermosonication), pressure (manosonication), or both (manothermosonication), appears to have greatest potential for industrial applications (Stratakos, 2015, cited in Galanakis, 2016).

2.1.5.3 High Pressure Processing (HPP)

High pressure processing (HHP) is a leading nonthermal food processing technology that is frequently mentioned as a major technological innovation in food preservation (Doona, 2007). In HHP pressure in the range of 200-1000 MPa employed to the foods (Tokusoglu and Swanson, 2015). A typical high-pressure system consists of a pressure vessel and a pressure-generating device. Food packages are loaded into the vessel and the top is closed. The pressure medium, usually water, pumped into the vessel from the bottom. Once the desired pressure reached, the pumping is stopped, valves are closed, and the pressure can be maintained without further need for energy input. The main working principle in HHP is that high pressure applied in an isostatic manner such that all regions of the food experience a uniform pressure, unlike heat processing, where temperature gradients are established (Doona, 2007). In order to ensure financial feasibility and environmental sustainability, HHP treatments must be kept short. Different applications of HHP in food processing is summarized in Figure 2.3 below.

Figure 2.3 Usage area of HHP
(Source:Tokusoglu and Swanson, 2015).

HHP has emerged as a capable commercial alternative for the pasteurisation of value-added fruits, vegetables, meat, and seafood products. HHP also has the capacity to inactivate *Clostridium botulinum* and other bacterial spores (Doona, 2007). HHP technology contributes to have fresh-like and better-quality food products that are safely enjoyed by the today's consumer. However, it has some disadvantages like resistance for inactivation of some food enzymes, leading to possible enzymatic and oxidative degradation of food components during storage and distribution (Thakur and Nelson 1998, cited in Galanakis, 2016).

HHP recently successfully applied to modulate food fermentations, possibly leading process with novel characteristics or development of new fermentations for the food industry (Mota et al. 2015, cited in Galanakis, 2016). Another promising application that is developed very recently is hyperbaric storage, a new food preservation method under high pressure (Galanakis, 2016). The aim in this method is to inhibit microbial growth, similarly to freezing and refrigeration, but at uncontrolled room temperature (Fernandes et al., 2015, cited in Galanakis, 2016).

2.2 An Overview of Consumer Attitudes on Emerging Novel Food Processing Technologies

2.2.1 Consumer Attitudes on Emerging Novel Food Processing Technologies (General)

Consumer acceptance of the food products that are developed by novel processing technologies, is essential. In food markets, "consumer is always right" so public reaction is a crucial factor in developing and introducing these technologies (Evenson, 2004).

There is extensive literature on consumer acceptance and perception of emerging novel food processing technologies. The International Food Information Council (IFIC) conducted a survey in 2012 on "consumer perceptions of food technology". 750 adult consumers were surveyed in United States through online survey tool. According to the survey results; 69% of the participated consumers have confidence in U.S food supply and safety and the same majority (69%) of the consumers would likely buy foods improved through biotechnology whereas in Europe, the situation different than in US. In 2013, a survey conducted by Eurobarometer (European Commission 2013) to investigate European citizens` attitudes toward science and innovation in general. Data were collected from 27,563 respondents from member states. The results of this survey may be reflective of European consumers` attitudes toward innovative food processing methods. 75% respondents agree that science and technology have provided more opportunities for future generations. However, Europeans are concerned about the speed of change of science and technology have, and their potential for negative consequences: 62% think science makes their way of life change too quickly. Europeans expressed their concerns on risks to human health and the environment. 76% think that research and innovation should be conducted with giving attention to ethical principles and public involvement. According to this

surveythe source of information most Europeans rely on to learn about new developments in science and technology include television (65%), newspaper (33%), websites (32%), and magazines (26%).

Rollin et al. (2011) investigated attitudes of consumers in Europe on 5 emerging food processing technologies; nanotechnology, genetic modification, nutrigenomics, food irradiation and animal cloning through the literature research. It is stated that; European consumers has a tendency to avoid risks and they demand transparency in the decision-making process of regulatory bodies. Taste found to be the most important factor for consumers that effect decision making process while purchasing food. It is found that more than %50 of US consumers are willing to buy GM food if it has more improved flavour. Naturalness is one of the important factor that affects purchase decision of consumer especially for nanotechnology food products. On the other hand, "price" found to be having limited importance in purchase decision process of consumers. It is stated that increased knowledge about food safety affects willingness to buy irradiated meat products. Acceptance of animal cloning technology of European consumers found to be low.

Frewer et al (2011) examined consumer acceptance of seven food processing technologies (GM Foods, Animal Cloning, Nutrigenomics, Nanotechnology, High Pressure Processing (HHP), Pulsed Electric Field (PEF)) by literature review. It is concluded from the research that in Europe, GM Foods and GM animals are mostly refused by the consumers. It is also found that, food irradiation is the technology which people perceived many risks. HHP and PEF are generally accepted technologies by the public because consumers perceive mainly benefits not risks with these technologies. On the other hand, awareness on nanotechnology in food processing found to be low.

Barrena et al. (2012) researched the relationship between consumer values and novel food acceptance. For this study three types of product were selected; a traditional coffee product and an innovative product produced from coffee (Nespresso type coffee capsules) and an ethnic product; couscous was selected as 3rd one. A survey was run between 2009 and 2010 in Spain in order to collect data. 116 consumers participated to coffee survey, 167 consumers participated couscous survey. A technique called "laddering" used in the interviews. Laddering interviews are personal, individual, in-depth, semi-structured interviews in order to find attribute-consequence-value relations on a particular food product. Socio-demographic variables like gender, education level, household size was found to be insignificant in accepting the food products. The research showed that consumer acceptance of food products largely depends on taste, price, ease of preparation and appearance.

Vidigal (2015) conducted a survey-based research by collecting data from 389 participants in Brazil. Food Technology Neophobia Scale (FTNS) is used to investigate consumers' perceptions and willingness to try food products; yogurts labelled as traditional, pasteurized, organic, genetically modified, enriched with bioactive proteins and nanotechnology. The average score of neophobia toward novel food technologies found to be 47.0. It is found that, Food technology neophobia directly affected from gender/marital status/number of family members. Also age, education level and income had an important effect on food technology neophobia. According to study willingness to try foods produced by nanotechnology was lower than foods produced by traditional and pasteurized methods.

According to Frewer et all (2003); the acceptability of a new production technology depends on the risks and benefits that are perceived by the consumers. Siegrist (2008) also investigated the factors that affect public acceptance of innovative technologies in the food

production and stated that the most important factors are; perceived benefit, perceived risks and perceived naturalness. When perceived risk and benefits are not clear for the consumers, trust to policy makers and producers become an important factor that influence public acceptance. According to Siegrist (2008), psychological constructs, like food neophobia also affect acceptance decisions of novel food technologies.

Siegrist (2000) stated that trust towards organisations working on food production and regulation issues may also have effects on perception of risks and benefits on the emerging technologies.

2.2.2 Consumer Attitudes on Genetically Modified Foods

Biotechnology is rapidly growing area and have a great potential but the significant economic and social benefits of modern biotechnology may not be realized if consumer acceptance issues are not adequately addressed (Stenholm, 1992, cited in Roller 1998). When a food product be marketed and it is rejected by the consumers, problems will arise like wasted R&D resources and spreading negative public reaction to one another rapidly.

It is claimed that biotechnology has replaced nuclear power as the symbol of "technology out of control", with little reference being made to the positive benefits (Nelkin, 1995, cited in Roller 1998). So it is recognized by most experts that public knowledge and perceptions of biotechnology must be systematically and effectively evaluated (Roller,1998).

In 2010 a survey conducted by Eurobarometer to find out what are European consumers are thinking on different applications of biotechnology. The survey also covered the area of GM and GM foods. A large majority of survey participants (84%) indicated that they have heard about GM foods, so the awareness level was high. 70% of the respondents express that GM foods are unnatural, 61% agree that GM foods make them feel anxiety, 61%

disagree that the development of the GM foods should be encouraged, 59% disagree that GM foods are safe for their health and 58% disagree that GM foods are safe for future generations. More than 75% believe that GM food production would harm the environment. The results of Eurobarometer (2010) survey showed that there were a general negative attitude toward GM foods among the European consumers.

Opinion of the consumers have a potential to change over time so GMO is also included in order to see whether there is a change in consumers` opinions.

2.2.3 Consumer Attitudes on Irradiated Foods

According to Sommers (2006), acceptance of irradiation has been slowed by several factors;

- The term "irradiation" is alarming consumers negatively because of its perceived association with radioactivity,
- The causes, incidence and prevention of food borne disease are poorly understood by the general public,
- Health professional and the media are largely unaware of the benefits of food irradiation.
- An anti-irradiation campaign has been conducted by certain activist groups because of their beliefs about food production issues, nuclear power, international trade, and industrialization, as well as the introduction of technologies.

A great number of studies in literature show that when a choice and a small amount of accurate information are given, consumers are willing to buy irradiated foods. Different market researches conducted in the last two decades showed that 80-90% of consumers

would accept irradiated products after they learn about it and understand the benefits (Sommers,2006).

2.2.4 Consumer Attitudes on Nanotechnology

Teagasc published a report named; "Irish Consumer and Industry Acceptance of Novel Food Technologies" in 2013. This report was an outcome of FIRM funded project of Teagasc Food Research Centre, University College Cork and Dublin Institute of Technology. Irish consumer acceptance and industry uptake of novel food technologies was investigated. Qualitative and quantitative methods were used in this research.

- Qualitative Method:

8 novel food technologies has been selected: Functional Foods, GM Foods, In Vitro Meat, Irradiated Foods, Nanofoods, Non-Thermal Technologies (High Voltage Pulsed Electric Field and High Intensity Ultrasound, Nutrigenomics, Thermal Technologies (Radio Frequency Heating and Ohmic Heating).

One-to-One "deliberate discourses" was designed between food scientists and consumers. 47 consumers participated in the discussion with food scientists. Each participant discussed one technology. The perceived risks and attitudes were examined. It is found out that environmental concerns, and animal welfare issues had an important role on consumer acceptance of novel food technologies. If the participants were not having knowledge about the technology, they tended to be more cautious about it.

- Quantitative Method

Quantitative analysis focused specifically on nanotechnology with two applications: using nanotechnology in food and use of nanotechnology in food packaging. 1046 participants answered the questionnaire in 2011. %22 of the participants had heard about nanotechnology. The acceptance of nanotechnology in food packaging was higher than foods that are produced by nanotechnology. But when compared with conventional

production methods; it is found that Irish consumers had a negative perception towards nanotechnology. Great importance was given by Irish consumers to nature and environmental protection. Also, it's observed that ethical issues and animal welfare are very important in the acceptance of technologies in Ireland. It is stated that there were no socio-demographic differences between the consumers who accepted/rejected nanotechnology applications in food industry.

2.2.5 Consumer Attitudes on Thermal and Non-Thermal Emerging Food-Processing Technologies

Sorenson (2009) investigated consumers' attitudes and perceptions towards novel processing technologies, specifically high pressure processed chilled ready meals. Laddering, in-depth interviews were conducted; 40 consumers participated these interviews who buy ready to eat chilled foods. The participants were between the age of 18 and 44 who are living in Dublin, Ireland.

Sorenson &Henchion (2009) stated that the most important factors that affect consumer acceptance of novel foods are:

- The degree of consumer involvement and food technology neophobia
- Trade-offs between perceived benefits and risks
- Unforeseen risks
- Social and moral concerns about long term effects of novel processing technologies
- Perceived threat to the food chain and environment
- Consumer characteristics such as cultural, psychosocial and lifestyle factors
- Nature of the benefits
- Trust in key stakeholders

The interview questions were designed to get answers on:

- Purchase behaviour and consumption habits for chilled ready meals
- General attitudes towards chilled ready meals
- Consumers' attitudes and perceptions towards high pressure processed ready to eat chilled meals.

The data analysis was done by using SPSS program.

It is concluded from this study that;

- The enhanced nutritional profile of chilled ready meals causes more consumer acceptance especially for families.
- Communication strategies with consumers are very important in new product development stage in order to prevent misconceptions.
- Perception of "naturalness" and "home madeness" is very important in consumer acceptance concept because these concepts linked to perception of healthiness.
- Integrating consumers with novel food processing process is extremely important.
- The extended shelf life concept is very important for the participants whom are in pre-family stage.

Chapter 3. Research Methodology

3.1 Survey Method

Quantitative research conducted via collecting data with online survey. Quantitative research is based on (Saint-Denis, 2018);

- Large sample size (n≥100 up to 1000)
- Advanced and multivariate statistical techniques
- Numbers and percentages collected across the sample (percentages are only expressed when sample size of main or sub-group is ≥100)
- Mostly close-ended questions (Verbal scales, multiple choice lists or Yes/No)

Quantitative studies generally provide more statistical elements to generalize results to a larger population and support decisions (Saint-Denis, 2018). In this study, participants were asked 42 questions regarding their demographic characteristics, attitudes, awareness and risk-benefit perceptions. This web-based survey can be found in Appendices part of this study.

According to Malhotra (2017), the advantages of survey method are; administering the questionnaire is simple, the data obtained are consistent because the respondents are limited to alternatives stated, the use of fixed-response questions reduces the variability in the results that may be caused by differences in the interviewers and it is also relatively simple to code, analyse and interpret the collected data.

Malhotra (2017) also stated disadvantages of survey method as; participants may be unwilling or unable to give desired information and they may not be consciously aware of their motives towards the subject (eg; specific food processing technology). Another disadvantage is that structured questions and fixed-response questions may result in loss of validity for certain types of data; like beliefs and feelings,

In this study survey method decided to be the most relevant data collection method in order reach the research objectives. According to Malhotra (2017), survey questionnaires may be conducted in 4 possible ways; online surveys, telephone surveys, face-to-face surveys and postal surveys. In this study, online self-completion mode was selected as a data collection method. SurveyMonkey (www.surveymonkey.com) online survey software program was used to design and disseminate survey link to the potential respondents in Ireland. The software also allowed filling in the questionnaire by using mobile devices easily. With online questionnaires; there is a possibility that respondents can go back over questions that they answered either to check or to change their previous responses. There is no time pressure on the survey participants. Web-based surveys have found that they are completed more quickly than other versions of surveying with face-to-face or telephone so that can help the respondents to enjoy filling in the questionnaire (Brace, 2018).

On the opening screen of the online survey in SurveyMonkey software; respondents were welcomed, the scope and purpose of the survey was explained. Information about total number of the questions and the average time that takes to complete the survey was also given in the welcome page.

3.2 Questionnaire Design

Malhotra (2020) stated that any questionnaire has three specific objectives, it must; translate the information needed into a set of specific questions that the respondents can and will answer, uplift motivate and encourage the respondent to become involved in the interview, to cooperate and to complete the questionnaire. Malhotra (2020) also stated that the researcher should keep in mind to minimise the response error while designing the questionnaire.

Questionnaire design process explained by Malhotra (2020) in Figure 3.1 below.

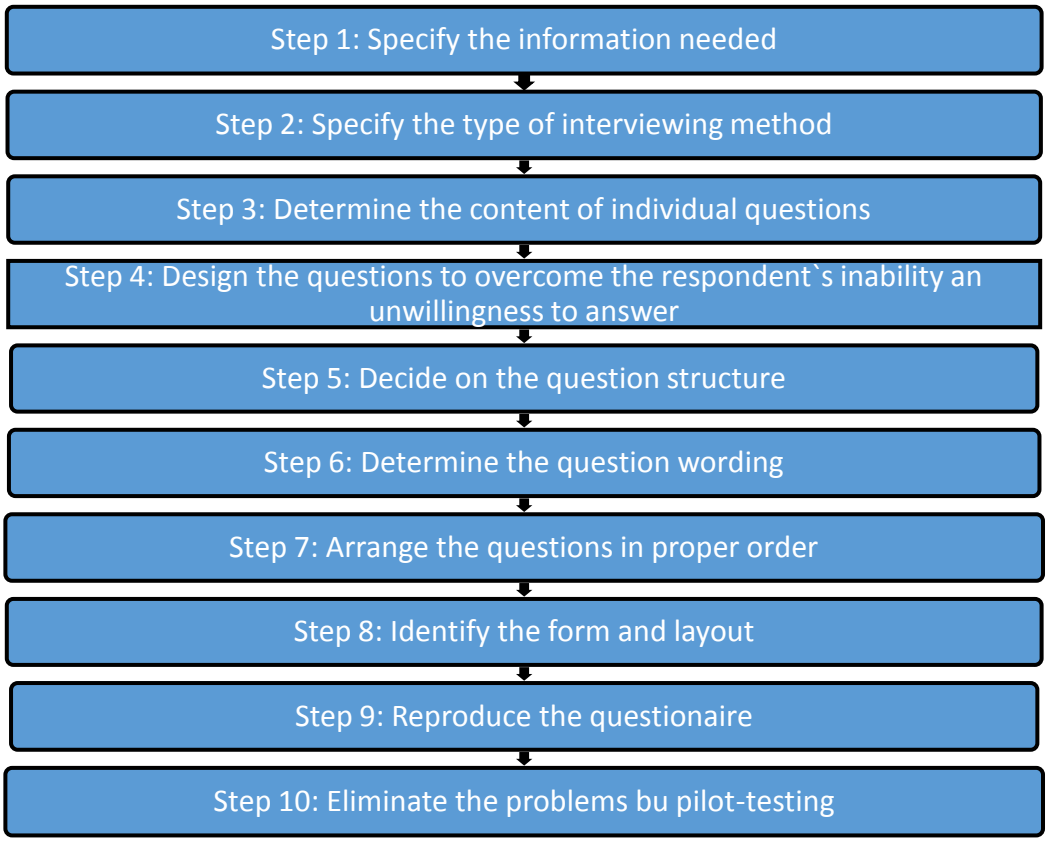

Figure 3.1 Questionnaire Design Process
(Source: Malhotra (2020)

In this study, these steps in above figure (Figure 3.1) carefully examined and in the light of this process questions are determined. Therefore, it was ensured by the researcher that the information and data which are obtained from the questionnaire fully addressed the research objectives.

3.3 Description of the Questionnaire

The survey (Appendix) contained 5 sections and included questions on;

- Socio Demographic Profile,
- Awareness/Trust,
- Risk and Benefit Perception,
- Willingness to try foods produced by novel processing technologies,
- Acceptance

The first part was about sociodemographic characteristics of the respondents including; gender, age, education, place of residence and marital status.

In order to measure the awareness of the consumers; the following question for each 5 novel food processing technology was asked;

- *How much have you heard about…?* The participants could mark their opinions as;

1) Nothing at all, 2) A Little, 3) Some, 4) A lot.

Participants' trust rates to the organisations which have a role in food processing and marketing were measured by using 5-point scale; 1) Very Trustworthy, 2) Somewhat Trustworthy, 3) Neither Trustworthy nor Untrustworthy, 4) Somewhat Untrustworthy, 5) Very Untrustworthy.

Participants were asked how concerned they are about eating foods that had been processed by each novel food processing technology. They could indicate their level of concern by a 5-point scale; 1) No concern, 2) Slight Concern, 3) Moderate Concern, 4) High Concern, 5) Uncertain.

The respondents presented their perceptions of risk and benefits on the five novel food processing technologies.

The level of acceptance of the each technology were measured by using 5-point scale; 1) Totally Acceptable, 2) Somewhat Acceptable, 3) Neither Acceptable nor Unacceptable, 4) Somewhat Unacceptable, 5) Totally Unacceptable.

3.4 Distribution of questions

The potential respondents were invited by the web-link via e-mail, Facebook, Linked-in and Instagram. While sending the survey web-link; the purpose and scope of the research were explained. The targeted participants were all consumers who are living in Ireland (18 years old or above). The survey software allowed to store the collected data on the website which can be reached by the individual account. It also allowed to download the data in excel format in order to use it in data analysis in SPSS.

3.5 Limitations of survey method

A major disadvantage of online surveys is not having an interviewer on hand to clarify questions and to avoid misunderstandings (Brace, 2018). In order to prevent misunderstandings, survey questions were prepared as clearly as possible. In order to eliminate any possible problems that respondents may have, the survey pilot tested by 4 representative candidates in order to test the validity of the questionnaire 1 week before the distribution. The researcher reviewed the questions according to respondents' suggestions at the pilot testing period.

3.6 Data Analysis

Before conducting the statistical analysis, the raw data must be converted into a form that is suitable for the analysis. Malhotra (2020) identified this conversion process as "Data Preparation" phase. In data preparation phase of this study; questions were checked for completeness and any missing responses are dropped from the analysis. In this study, the entire response rate was 453, however for each statistical analysis, valid response rate changes according to the validity of the response. Not all respondents completed the questionnaire so for example only 305 responses could be used in conducting cluster analysis in this study.

Coding, which means assigning a number to responses, made before starting the data analysis. The researcher assigned a code for each response to each question. Once the data was prepared for analysis, quantitative data analysis techniques were used in this study. These techniques are;

- Descriptive Statistics
  - Frequency Distribution; one variable is considered at a time.

The objective is to obtain a count of a number of responses associated with different values of the variable (Malhotra, 2020). In this study frequency distribution tables and pie-bar charts are used in order to present the data in a coordinated form.

- Consumer Segmentation/Cluster Analysis

The primary objective of cluster analysis is to classify responses into relatively homogenous groups based on the set of variables (Malhotra. 2020). The details of this method is explained in section 4.2 below.

- Statistics for Comparison
  - Cross-tabulations with Chi-Square Test.

Cross tabulation describes two or more variables simultaneously (Malhotra, 2010). This technique is used to understand how one variable such as gender relates to another variable such as acceptance. P-value is used in chi-square test to determine whether there is a significant difference between the variables.

P-value>0.05 no significant difference

P-value<0.05 there is a significant difference

3.7 Consumer Segmentation/Cluster Analysis

Segmentation is important in consumer research. It helps to understand consumer behaviour better by focusing on the individual differences among consumers (Ares, 2018). There are two types of segmentation; priori and posteriori segmentation (Brockhoff 2010, cited in Ares 2018, p354). In priori segmentation; segments are identified by consumer variables like; gender, age or attitudes. On the other hand, in posteriori segmentation, consumers who responded similarly are grouped together (Ares 2018). Posteriori segmentation is also called unsupervised segmentation and segments are identified by cluster analysis (Ares 2018). Cluster analysis helps to maximize homogeneity within groups and maximize heterogeneity between groups (Mazzocchi 2008, cited in Ares 2018, p355).

The aim of the segmentation is to find similarities among the customers and to determine groups in the data. Depending on the data input, the similarities can be defined.

Malhotra (2020) listed the steps in cluster analysis as in Figure 3.2. In this study the researcher followed these steps in conducting cluster analysis.

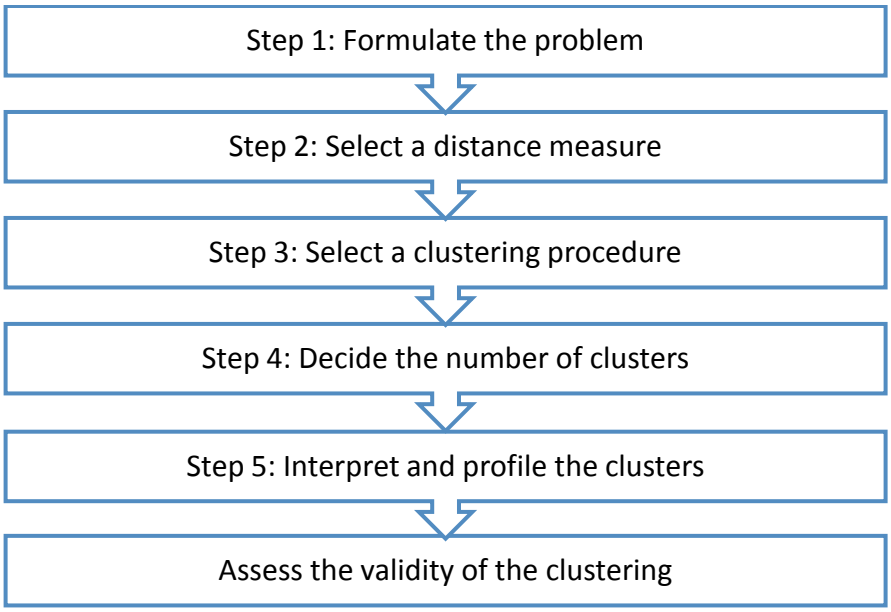

Figure 3.2 Steps of cluster analysis
(Source: Malhotra, 2020)

Cluster analysis can be done by different methods and techniques. There are two main methods in cluster analysis; hierarchical methods and the partitioning methods (Naes et al., 2010). In hierarchical approach, all consumers are considered separate clusters, then these clusters are merged according to which are closest (Ares, 2018). When two clusters K1 and K2 are to be merged, the distance between these two can be calculated. Computing the distance between clusters is called *linkage* (Ares, 2018). Linkage method allows to define how the intercluster distance is calculated and how different the clusters to be linked.

There are five different types of linkage (Ares, 2018);

1- Single Linkage

2- Complete Linkage

3- Ward Linkage

4- Average Linkage

5- Centroid Linkage

Sajdakowska et al. (2018) successfully applied Wards hierarchical clustering method in order to identify homogeneous groups based on opinions on the technologies in the production of cereals and cereal products. In this research, Ward's hierarchical method was also used in order the identify clusters. In Wards linkage; at each step in the analysis, the union of every possible pair of clusters is considered, and the solution with the smallest increase in the inner sum of squares is selected (Ares, 2018).

Choice of clustering method and choice of distance measure are interrelated, for example; squared Euclidean distances must be used in Ward`s method (Malhotra, 2020). In this study the distances calculated by SPSS method using the below equation:

Euclidean distance d_{ij} is the distance and defined by the equation;

$$d_{ij} = \sqrt{\left(\sum_{k=1}^{K}\left(y_{ik} - y_{jk}\right)^2\right)} \qquad \text{(Naes et al. 2010)}$$

Where *i* and *j* represent two different objects (consumers).

The most important part of the cluster analysis is the formulating the clustering problem by selecting variables (Malhotra, 2020). In this study, responses to awareness, concerns and acceptance questions in each emerging novel food processing technology are defined variables that will be used to base clustering of the consumers.

The results of hierarchical clustering are summarized in so-called dendograms (Naes et al., 2010). Dendogram is a tree diagram that illustrates the structure of the clusters and allow to inspect the results visually. Vertical lines represents clusters that are joined together. The

position of the line on the scale indicates the distances at which clusters are joined (Malhotra, 2020). The dendogram is read from left to right.

An agglomeration schedule of this study is also attached in Appendix. It gives on information on the responses being combined at each stage of a hierarchical clustering analysis (Malhotra, 2020).

3.8 Consumer Science Approaches

A number of theories have been developed in order to assess consumer response to innovative food processing. These theories were;

- The theory of planned behaviour (TPV) (Ajzen 1991, cited in Galanakis 2016, p273),
- The technology acceptance model (Davis 1989, cited in Galanakis 2016, p273),
- Diffusion of innovations (Rogers 1962/1995, cited in Galanakis 2016, p273),
- The health belief model (Janz&Becker 1984, cited in Galanakis 2016, p273),
- The protection motivation model (Prentice&Rogers 1986, cited in Galanakis 2016, p273),
- Risk-Benefit Perception and trust-knowledge studies (Galanakis, 2016).

The theory of planned behaviour (TPB-Figure 3.3) is one of the most frequently applied models for predicting consumer preference formation (Galanakis, 2016). It predicts consumer behaviour from the intention of the consumer to conduct that behaviour. It also estimates the perceived control that the consumer has about the behaviour (Galanakis, 2016). Intentions are formed by attitudes, social norms and perceived behavioural control.

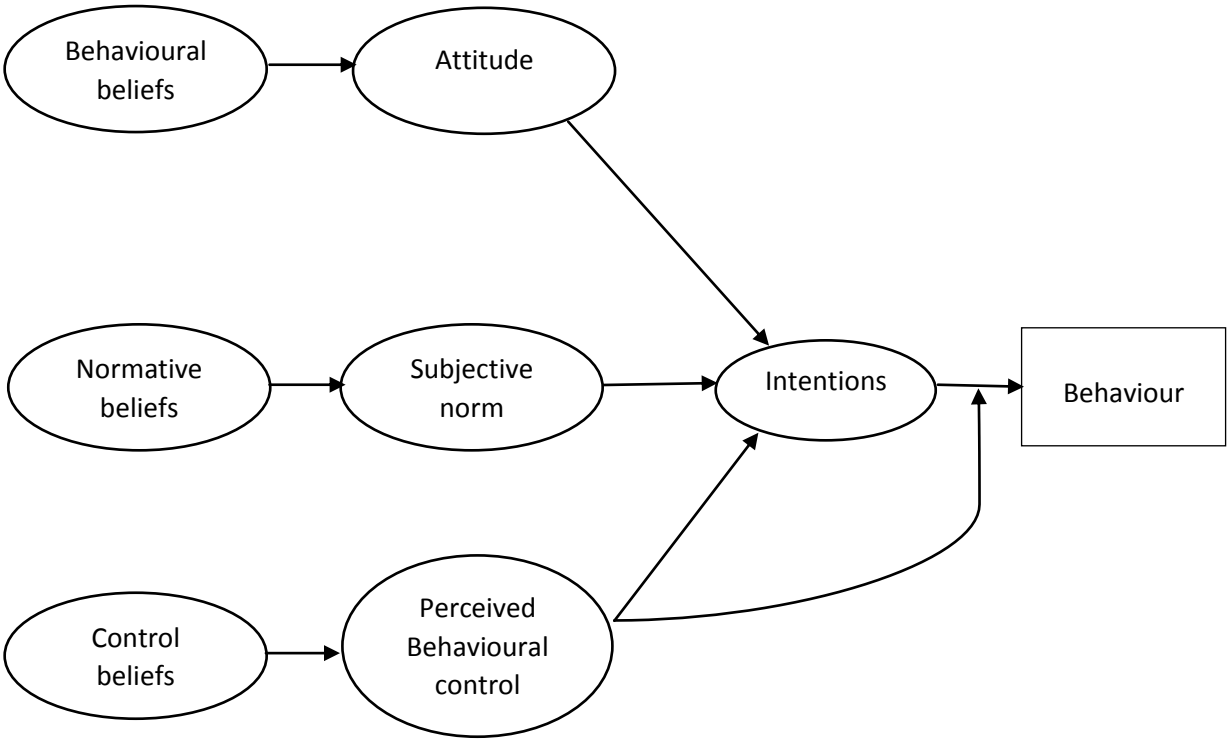

Figure 3.3 Theory of planned behaviour
(Source: Galanakis, 2016)

Technology acceptance model (TAM-Figure 3.4) is another frequently used model in understanding consumer responses. Like TPB it predicts the use of technology from attitudes toward that technology (Galanakis, 2016). Then the attitudes are predicted by perceived usefulness and ease of technology (Galanakis, 2016).

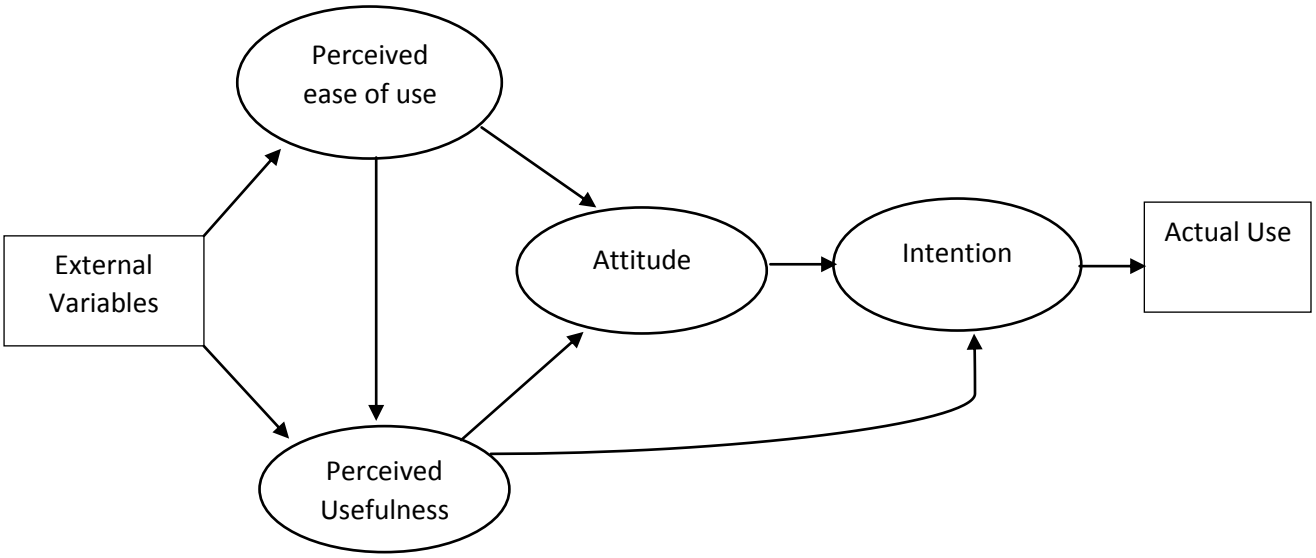

Figure 3.4 Technology acceptance model
(Source: Galanakis, 2016)

The health relief model focuses on motivations why and when perceived threats to personal health result in consumer behaviour. Basing on the ideas raised in health relief model, a new model focusing on avoiding risks was developed in the protection motivation model (Rogers 1983, cited in Galanakis 2016, p275). It is found that risk-benefit perception (Figure 3.5) has a very important role in consumer behaviour; perceived risks negatively affect acceptance, on the other hand, perceived benefits affects positively (Galanakis, 2016). Several studies showed that trust in the agent, producer or government is an important factor in reducing risk perception and increasing benefit perception (Frewer et al, Siegrist et al, cited in Galanakis 2016).

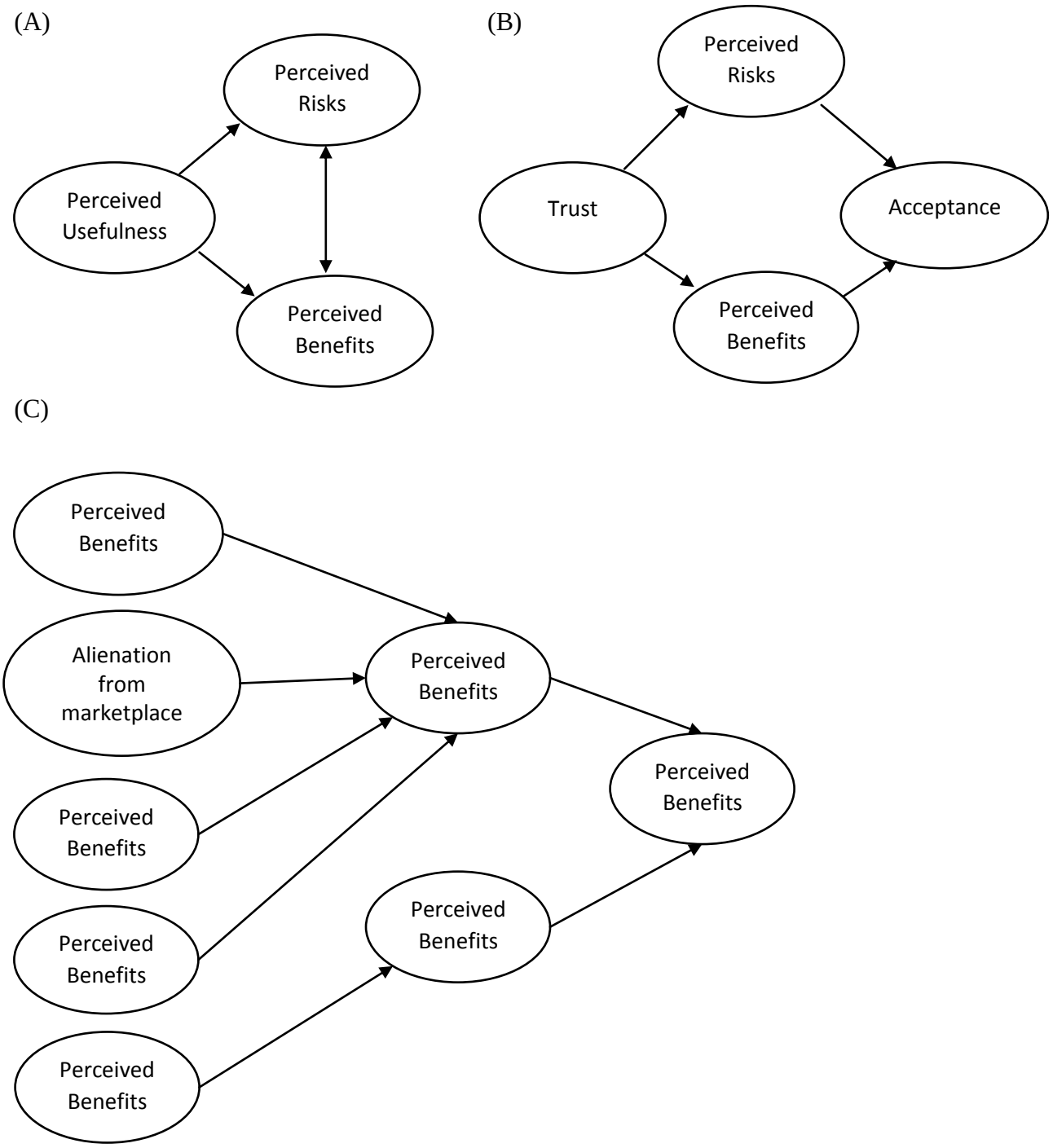

Figure 3.5 Risk-Benefit Model
(Source: Galanakis, 2016)

In general, consumer acceptance of novel technologies is often perceived as positive when there are well communicated benefits associated with the technology as well as the output product resulting from the novel technology. This is not always true for technologies and products in food processing area and the researcher aimed to investigate it. Consumers are particularly conservative when it comes to perception and acceptance of foods compared to other products (Ueland et al, 2012). Unfamiliar, uncertain, unknown, uncontrollable, and severe consequences are some factors associated with risk perception (Ueland et al, 2012). Novel food processing techniques score high on several of these parameters and are perceived as risky by consumers. Understanding how consumers perceive benefits and risks of foods, may contribute to figure out benefit-risk perception in other areas related to personal, societal or environmental perspectives (Ueland et al, 2012). In this study risk-benefit perceptions of each novel food processing technologies are investigated in order to assess consumer response to these technologies.

4. Results and Discussion

4.1 Overview

In this chapter, the statistical analysis of the data and the findings of the questionnaire are presented. A statistical analysis software package; SPSS is used in the data analysis part of this study. Microsoft Office Excel is also used to design some tables and charts. Discussion paragraphs are included after presenting the results in each section.

4.2 Results

4.2.1 Demographic profile of the respondents

Place of Residence (Figure 4.1): 451 participants answered this question. 71.84% of the respondents are living in City/Town while 28.16% are living in Countryside.

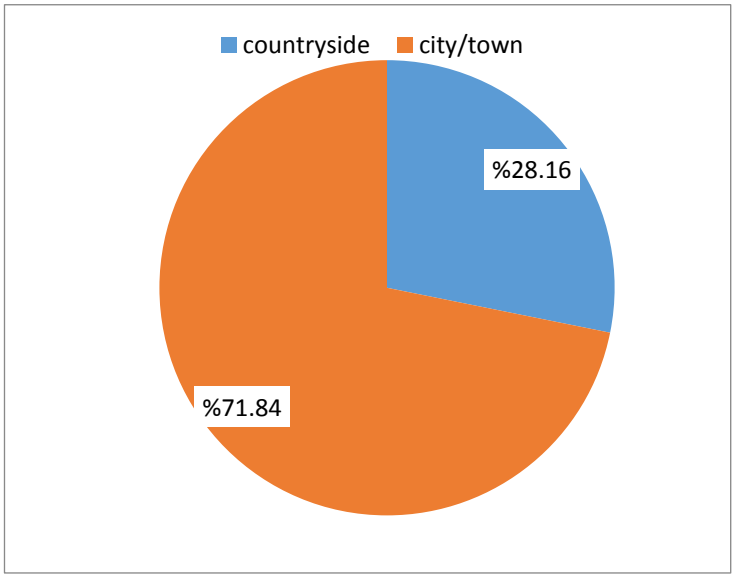

Figure 4.1 Pie chart of place of residence of respondents

Gender (Figure 4.2): Among the 451 respondents; 338 are female, 109 are male and 4 of them indicated their gender as "other", these numbers account for 74.94%, 24.17% and 0.89%, respectively.

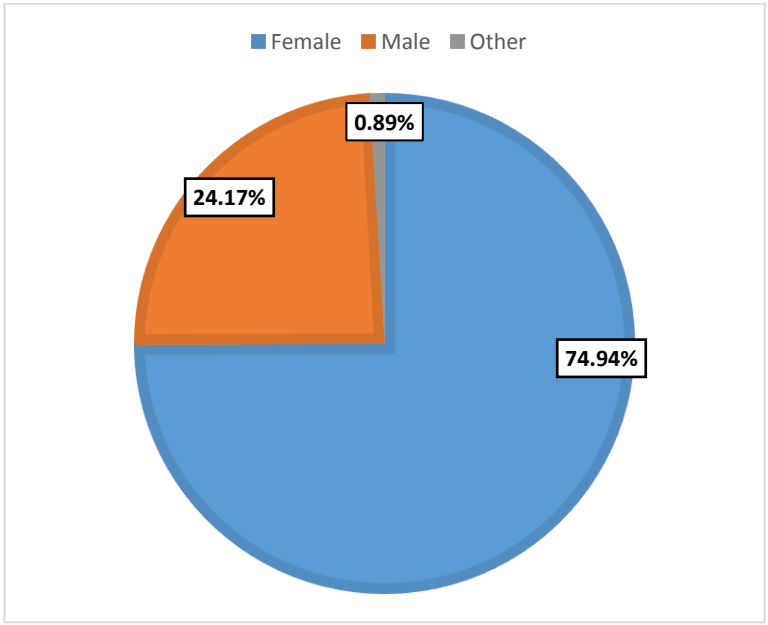

Figure 4.2 Pie Chart of Gender of the Respondents

A higher percentage of the respondents were female (74.94%). The reason of high level of participation of women but lower participation of men may be that women generally have a role of food provider to family. As a consequence, women may have more interest on surveys that are related with food.

Age of respondents (Figure 4.3):(Valid N=451) Respondents were within the age range of 36 to 50 years (37.92%), 26 to 35 years (26.83%), 51 and above (24.39%) and 18 to 25 years (10.86%).

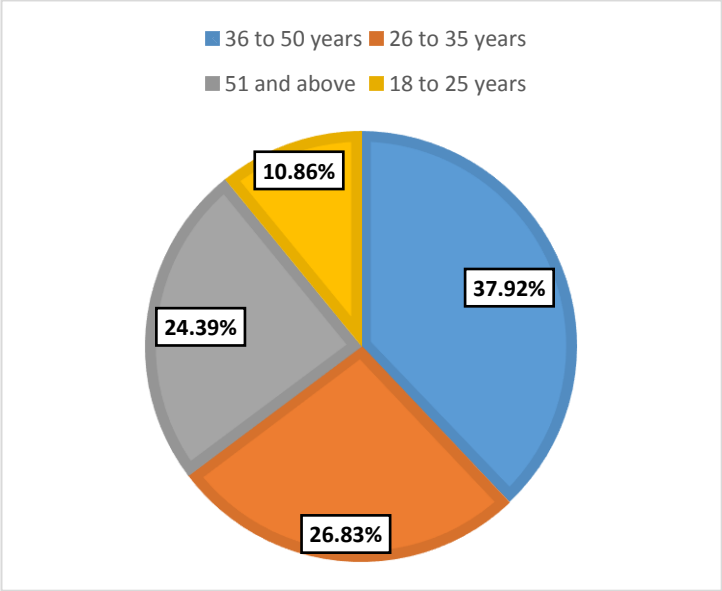

Figure 4.3 Pie chart age of respondents

Level of Education (Figure 4.4):(Valid N=450). The educational levels of the participants were as follows:

- Secondary education or less (12.67%);
- High school graduates (13.11%);
- Graduate degrees (46.89%); and
- Postgraduate degrees (27.33%)

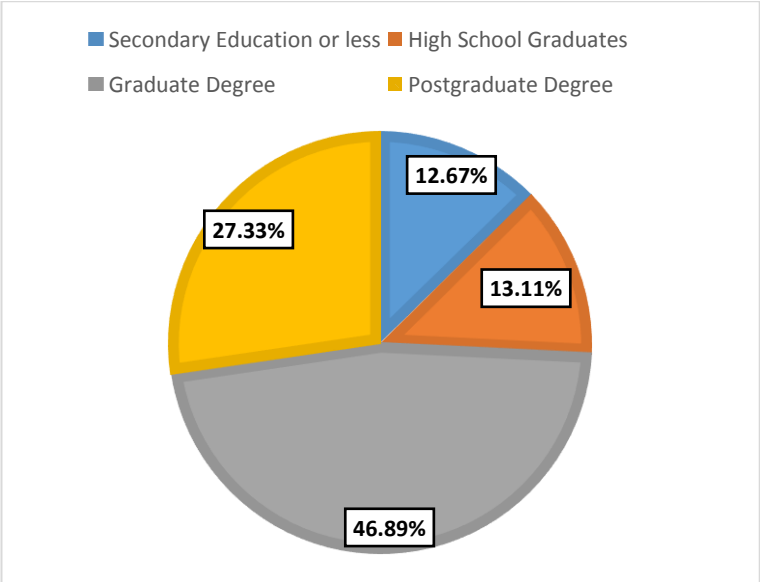

Figure 4.4 Pie Chart of Education Level of Respondents

Marital Status (Figure 4.5): (Valid N=450) 29.33% of the respondents were single, 60.00% were married and 10.67% indicated their marital status as "other".

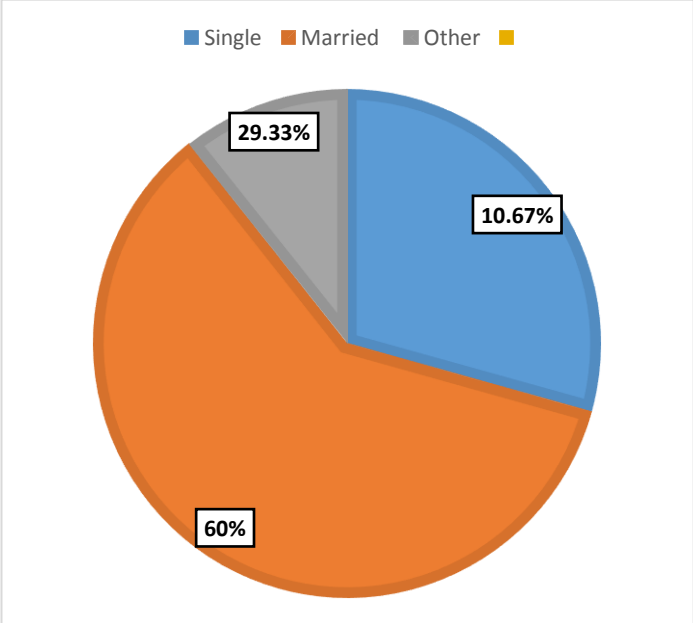

Figure 4.5 Pie chart of marital status of the respondents

Experience in food processing area (Figure 4.6): (Valid N=430) 24.19% of the participants have food processing background (worked or studied) while 75.81% of them does not have any working or studying experience in this area.

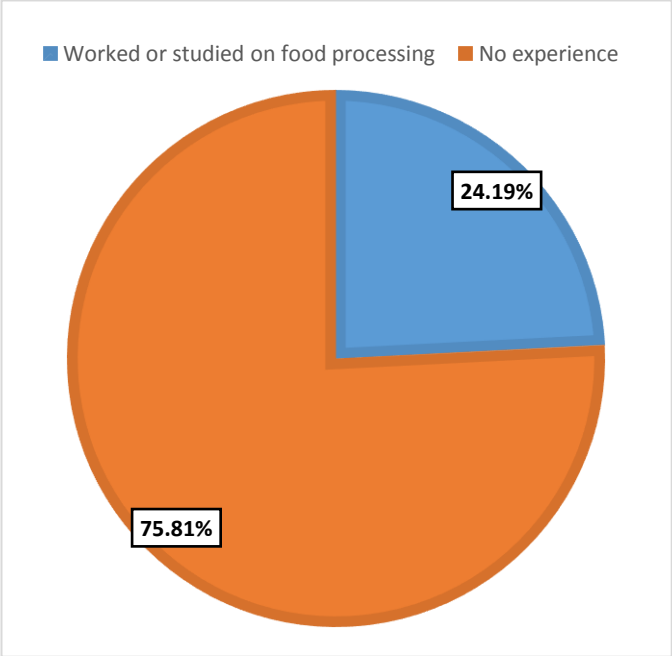

Figure 4.6 Pie Chart showing respondents` food processing background

Nationality (Figure 4.7): Nationality question was added into survey in the second week of distribution so valid responses was 264. 73.11% (193) of the respondents are Irish, 26.89% of them are belongs to other nationalities.

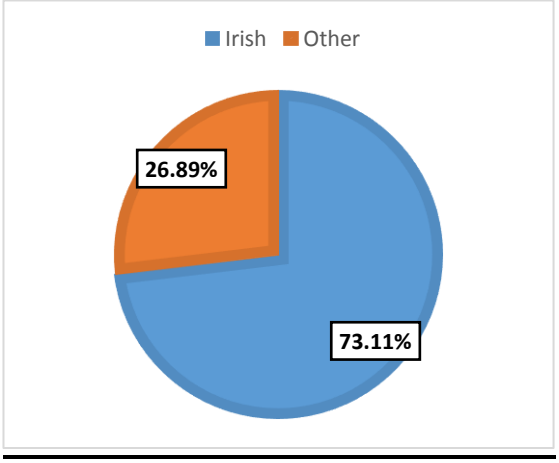

Figure 4.7 Pie Chart of nationality of the respondents

Irish Provinces that the respondents living (Figure 4.8): Province question was also added into survey in the second week of distribution so valid responses was 273. The distribution was as follows; Connact (4.03%), Leinster (64.47%), Munster (21.98%) and Ulster (9.52%).

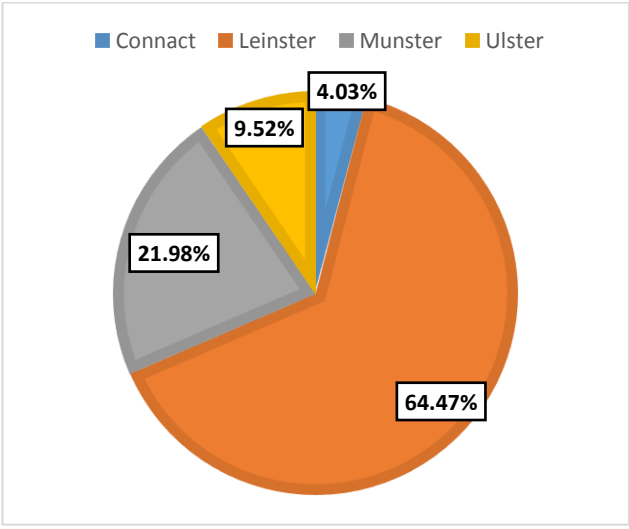

Figure 4.8 Pie chart of respondents` provinces

4.2.2 Level of Knowledge of the respondents

It can be seen in table 4.1 below that majority of the consumers in Ireland have lack of knowledge on emerging novel food processing technologies except GMO, only 6.26 of the participants indicated that they heard nothing about it.

Table 4.1 Percent of (N=431) respondents that heard nothing about novel food processing technologies

Novel Food Processing Technology	**Response rate of "I heard nothing about this technology"**
GMO	6.26 %
Irradiation	50.35 %
Nanotechnology	58.00 %
Thermal Emerging Food Processing Technologies (Radio Frequency Heating and Ohmic Heating)	69.84 %
Non-Thermal Emerging Food Processing Technologies (Pulsed Electric Field (PEF), Ultrasound, High Pressure Processing (HPP)	73.72 %

Table 4.2 below indicates that, genetic modification and irradiation of foods evoked the most concern among the consumers (46.34% and 29.20% of respondents, respectively, were highly concerned with foods processed with these technologies). Thermal Emerging Food Processing Technologies (17.65%) and Non-Thermal Emerging Food Processing Technologies (14.32%) generated significantly less concern.

Table 4.2 Percent of (n=410) respondents that were "Highly Concerned" and "Uncertain" about the foods processed by novel technologies.

Food Processing Technology	**%Highly Concerned**	**% Uncertain**
GMO	46.34	4.63
Irradiation	29.20	31.63
Nanotechnology	20.54	38.63
Thermal Emerging Food Processing Technologies (Radio Frequency Heating and Ohmic Heating)	17.65	38.73
Non-Thermal Emerging Food Processing Technologies (Pulsed Electric Field (PEF), Ultrasound, High Pressure Processing (HPP)	14.32	40.74

A sharp negative reaction was observed in the use of GMO and irradiation in food production among consumers in Ireland (46.34% (GMO) and 29.20% (Irradiation) of 410 consumers were highly concerned). The majority of the participants stated that they have average knowledge on GMO but increased public knowledge does not always make it easy to accept the technology. The information that public have should be reliable and correct. Therefore, problem is not just poor knowledge in these technologies, it is necessary to analyse the causes of rejection of GMO and irradiation

deeper.GMO and Irradiation are still controversial among consumers in Ireland and according to this study they still appear to be associated with a negative public response.

Table 4.3 below show that the consumers` knowledge mostly rely on information from internet, social networks and television (46.04%, 27.23% and 24.50% respectively).

Table 4.3 Responses to the question: "Where have you heard of these technologies? (You can mark more than one)"

Answer Choices	**Responses**	
Television	24.50%	99
Internet	46.04%	186
Social Networks	27.23%	110
Newspaper	21.29%	86
School/University	20.54%	83
From friends or family	22.03%	89
Never heard about these	23.27%	94
Other (please specify)	3.96%	16
	Answered	**404**
	Skipped	**49**

According to table 4.3, the key source of information used by consumers are the media so the media play a significant role in the providing information. Public tend to believe what they read or see in media and their views are strongly affected by it. Especially when little known previously about the technology, the influence of media would be stronger. Therefore the credibility of the published information should be taken into account.

Providing reliable information about these technologies seem to be key to increase consumer acceptance. This is especially important in the case of irradiation and nanotechnology processing since many consumers associate the technology name with hazards and are sceptical about possible side effects. It would be useful to provide information about the processing technologies described on the package, allowing the consumer to recognize the advantages of these products.

4.2.3 Cluster Analysis

Cluster analysis is done in order to find groups in survey data. As it is explained in section 4.2 of this study; hierarchical clustering with Euklidean distances and Ward method was applied the data to set the cluster the valid N=305 consumers. The incomplete answers were eliminated. SPSS Version 26 programme was used to analyse the data.

As seen in table 4.4and figure 4.1 below, 3 clusters were identified based on the questionnaire. The inputs of the cluster analysis were the responses to the questions on knowledge, concerns and acceptance of novel food processing technologies. 3 clusters were identified;

Cluster I. Technology Enthusiasts (17.7%)

Cluster II. Technology Neutral (46.6%)

Cluster III. Technology Sceptics (35.7%)

Table 4.4 Cluster Analysis

Hierarcial Cluster Analysis by Ward Method					
		Frequency	**Percent**	**Valid Percent**	**Cumulative Percent**
Valid	Cluster 1	54	11,9	17,7	17,7
	Cluster 2	142	31,3	46,6	64,3
	Cluster 3	109	24,1	35,7	100,0
	Total	**305**	67,3	100,0	
Missing	System	148	32,7		
Total		453	100,0		

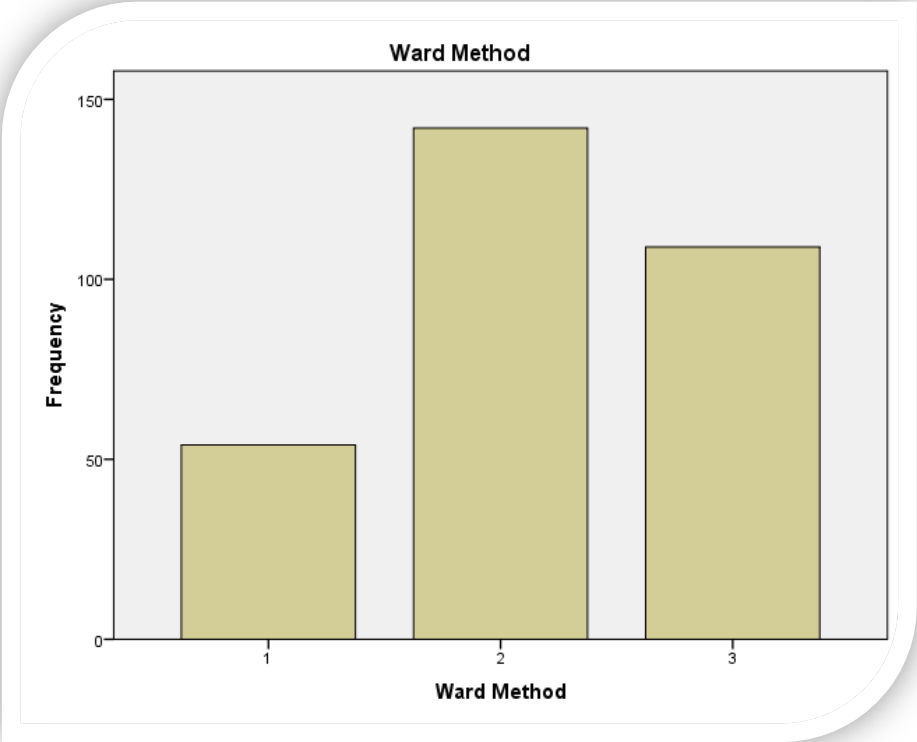

Figure 4.1 Chart of cluster analysis
1: Technology Enthusiasts, 2: Technology Neutral, 3: Technology Sceptics

Regarding the demographic characteristics of the respondents in cluster analysis (Valid N=305), the sample consists of more females than males. Most of the respondents (68.2%) were living in City/Town in Ireland. Respondents' education level was good as 78.68% of them completed graduate and postgraduate education. The detailed description of the sample, including socioeconomic characteristics, is summarized in Table 4.5 below.

Table 4.5 Demographic profile of consumers in each cluster
*** Frequency**

Variables	Total Sample (N:305)	Cluster 1. Technology Enthusiasts (Frq*) (N:54)	Cluster 1. Technology Enthusiasts (%)	Cluster 2. Technology Neutral (Frq*) (N:142)	Clluster 2. Technology Neutral (%)	Cluster 3. Technology Sceptics (Frq*) (N:109)	Cluster 3. Technology Sceptics (%)
Place of Residence							
City/Town	208	39	72,2	95	66,9	74	67,9
Countryside	97	15	27,8	47	33,1	35	32,1
Gender							
Female	218	30	55,6	100	70,4	88	80,7
Male	84	24	44,4	41	28,9	19	17,4
Other	3	0		1	0,7	2	1,8
Age							
18 to 25 years old	30	8	14,8	20	14,1	2	1,8
26 to 35 years old	88	18	33,3	41	28,9	29	26,6
36 to 50 years old	115	24	44,4	44	31	47	43,1
51 and above	72	4	7,4	37	26,1	31	28,4
Level of Education							
Secondary or less	30	0		20	14,1	10	9,2
High School Graduate	35	4	7,4	15	10,6	16	14,7
Graduate Education (eg: BSc, BSE, BA)	147	23	42,6	67	47,2	57	52,3
Postgraduate Education (eg: PhD, MSc, MA)	93	27	50	40	28,2	26	23,9
Marital Status							
Single	87	21	38,9	48	33,8	18	16,5
Married	188	28	51,9	80	56,3	80	73,4
Other	29	5	9,3	14	9,9	10	9,2
Have you ever worked or studied in food processing related area?							

Yes	83	38	70,4	28	19,7	17	15,6
No	221	16	29,6	114	80,3	91	83,5

Cluster I. Technology Enthusiasts

This segment consists of consumers who have favourable attitudes toward novel food processing technologies. The socio demographic profile of technology enthusiasts is composed of consumers with high education level. 42,6% of them completed graduate education and 50% of them completed postgraduate education. In terms of age, 14,8% were between 18 to 25 years old, 33.3% were between 26 to 35 years old and 44,4% were between 36 to 50 years old. When compared to other clusters, the respondents in this group have mostly (70.4%) worked or studied in food processing related area. Consumers in this segment have higher level of awareness on emerging food processing technologies and are mostly willing to buy food products that were processed with these technologies. They expressed considerable optimism regarding the commercialization of novel food processing technologies.

Cluster II. Technology Neutral

This segment consists of consumers who have neutral attitudes toward novel food processing technologies.As seen in table 4.3.3.2 above, demographic profile of technology neutral segment composed of mainly females (70.4%), married (56.3%) and middle aged consumers (31%). They are uncertain about the concerns on these technologies and could not be able to express a specific response to acceptance question.

Cluster III. Technology Sceptics

The respondents from this segment presented negative opinions on novel food processing technologies. This segment composed of mostly females (80.7%). 43.1% were between 36 to 50 years old and 73.4% were married. Only 15.6% of these group have some study or work experience in food processing area. When compared with Technology Enthusiasts and Technology Neutral segments, those consumers have

higher level of concerns on emerging novel food processing technologies and they find them mostly unacceptable.

Interestingly, the overwhelming majority of the customers in Cluster I (Technology Enthusiasts) had higher education level (42.6%-graduate and 50% postgraduate education). Also in this segment 70.4% of the consumers have background on food relating area (either study or work experience) sothe individuals with more formal education are more accepting the technologies. Therefore in the long term, the governments and authorities would focus on the education of teenagers who will be next generation consumers. That would have a potential to be more effective than short trainings with adults on novel food processing technologies.

Lack of knowledge among consumers in the Cluster 3 contributed to consumers` sceptism to thetechnologies. This segment mostly includes female (80.7%) and marrided (73.4%) consumers. Fox and Firebaugh (1992) showed in their study that women are more likely than men to question the utility of science. They conducted their study by investigating attitudes of genders investing on the space exploration. Keeping in mind that food is a more sensitive area; the present study is in line with Fox and Firebaugh (1992) results.

Accroding to Siegrist (2000) women are more reluctant to substitute new products than men. However, in the “technology enthusiasts”segment, no much diffference observed between the number of women and men respondents (55.6%-women, 44.4%-men). More studies including more male respondents are necessary to better understand gender reluctancy on the food that are produced by new technologies.

4.2.4 Risk&Benefit Perception

375 respondents answered the question; “Please mark the followings concerns that you think are related with the listed novel food technologies (You can mark more than one)”, and “Please mark the following benefits that you think are related with the listed novel food technologies (You can mark more than one)”

4.2.4.1 Risk-Benefit Perception of Genetically Modified Foods

Table 4.6 and 4.7 summarises the main outcomes for risk/benefit perception of GMO.

Consumers (N=375) expressed that they have more concerns about health, environment and unnaturalness issues regarding GMO (78.93%, 52.80% and 51.20% respectively). Only 6.13% of them indicated “No Concern” for genetic modification of food products.

On the other hand, majority believe that GMO technology have benefits on efficiency of production (48.83%), on economy (23.39%) and reduction in the use of pesticides (34.80%) (N=342).

Approximately 32% of the respondents do not perceive any benefits of GMO.

Table 4.6 Risk Perception of Genetically Modified Foods

Answer Choices	Responses	
Health concerns (Toxiological/biological concerns, allergenicity, unknown long term effects etc)	78.93%	296
Environmental concerns	52.80%	198
Concerns on unnaturalness	51.20%	192
Animal welfare concerns	28.80%	108
Worker safety concerns	13.60%	51
Radioactivity	14.40%	54
No concern	6.13%	23
Other (please specify)	2.13%	8
	Answered	**375**
	Skipped	**78**

Table 4.7 Benefit Perception of Genetically Modified Foods

Answer Choices	Responses	
Improve efficiency/yield of production	48.83%	167
Help country to compete/support of local economy	23.39%	80
Reduced pesticide use	34.80%	119
Enhanced food safety issues	13.16%	45
Result in fresher products, Better tasting/Enhanced flavour	19.30%	66
Result in more nutritious products	13.16%	45
Producing less waste	16.96%	58
None	31.58%	108
Other (please specify)	3.22%	11
	Answered	**342**
	Skipped	**111**

4.2.4.2 Risk-Benefit Perception of Irradiation

Table 4.8 and table 4.9 summarized the main outcomes of this question for Irradiation.

The majority of respondents (67.84%, N=370) stated that they have health related concerns about food irradiation technology. 35.41% have environmental concerns and 33.24% associated irradiation with "radioactivity". Only 11.35% of the respondents ticked "No Concern" as an answer.

About 41% of survey participants do not see any benefit of irradiation process. Approximately 18% of respondents stated that irradiation helps to enhance food safety issues.

Table 4.8 Risk Perception of Irradiation

Answer Choices	**Responses**	
Health concerns (Toxiological/biological concerns, allergenicity, unknown long term effects etc)	67.84%	251
Environmental concerns	35.41%	131
Concerns on unnaturalness	27.84%	103
Animal welfare concerns	15.41%	57
Worker safety concerns	23.78%	88
Radioactivity	33.24%	123
No concern	11.35%	42
Other (please specify)	8.11%	30
	Answered	**370**
	Skipped	**83**

Table 4.9 Benefit Perception of Irradiation

Answer Choices	**Responses**	
Improve efficiency/yield of production	15.81%	52
Help country to compete/support of local economy	8.51%	28
Reduced pesticide use	15.50%	51
Enhanced food safety issues	18.24%	60
Result in fresher products, Better tasting/Enhanced flavour	13.07%	43
Result in more nutritious products	5.17%	17
Producing less waste	15.50%	51
None	41.34%	136
Other (please specify)	9.12%	30
	Answered	**329**
	Skipped	**124**

4.2.4.3 Risk-Benefit Perception of Nanotechnology

Table 4.10 and table 4.11 summarized the main outcomes of this question for Nanotechnology.

The majority of respondents (59.23%, N=363) stated that they have high concerns about health issues regarding nanotechnology applications in food production. Consumers also expressed more concerns on environmental and unnaturalness issues (25.90% and 33.06% respectively). Only 17.63% are confident about nanotechnology and stated no concern.

Like in GMO and Irradiation, high number of respondents (39.45%, N=327) thinks that there are not any benefits in applying nanotechnology in food production.

Table 4.10 Risk Perception of Nanotechnology

Answer Choices	**Responses**	
Health concerns (Toxiological/biological concerns, allergenicity, unknown long term effects etc)	59.23%	215
Environmental concerns	25.90%	94
Concerns on unnaturalness	33.06%	120
Animal welfare concerns	11.29%	41
Worker safety concerns	10.47%	38
Radioactivity	11.29%	41
No concern	17.63%	64
Other (please specify)	9.37%	34
	Answered	**363**
	Skipped	**90**

Table 4.11 Benefit Perception of Nanotechnology

Answer Choices	Responses	
Improve efficiency/yield of production	26.61%	87
Help country to compete/support of local economy	14.98%	49
Reduced pesticide use	13.15%	43
Enhanced food safety issues	14.07%	46
Result in fresher products, Better tasting/Enhanced flavour	11.62%	38
Result in more nutritious products	9.79%	32
Producing less waste	11.01%	36
None	39.45%	129
Other (please specify)	11.01%	36
	Answered	**327**
	Skipped	**126**

4.2.4.4 Risk-Benefit Perception of Thermal Emerging Food Processing Technologies

Table 4.12 and table 4.13below summarized the main outcomes of this question for Thermal Emerging Food Processing Technologies (Radio Frequency Heating and Ohmic Heating)

Consumers (N=364) expressed more concerns about health, environment and unnaturalness issues regarding thermal emerging food processing technologies (58.52%, 25.27% and 29.95% respectively). 20.05% of them ticked "No Concern" option.

Respondents (N=324) indicated that benefits on efficiency, better food safety and fresher products exist (19.14%, 17.28% and 12.04 respectively) for this type of emerging technologies.

Table 4.12 Risk Perception of Thermal Emerging Food Processing Technologies

Answer Choices	**Responses**	
Health concerns (Toxiological/biological concerns, allergenicity, unknown long term effects) long term effects etc)	58.52%	231
Environmental concerns	25.27%	92
Concerns on unnaturalness	29.95%	109
Animal welfare concerns	8.52%	31
Worker safety concerns	11.54%	42
Radioactivity	14.56%	53
No concern	20.05%	73
Other (please specify)	10.16%	37
	Answered	**364**
	Skipped	**89**

Table 4.13 Benefit Perception of Thermal Emerging Food Processing Technologies

Answer Choices	**Responses**	
Improve efficiency/yield of production	19.14%	62
Help country to compete/support of local economy	10.49%	34
Reduced pesticide use	11.11%	36
Enhanced food safety issues	17.28%	56
Result in fresher products, Better tasting/Enhanced flavour	12.04%	39
Result in more nutritious products	5.56%	18
Producing less waste	10.49%	34
None	42.90%	139
Other (please specify)	11.11%	36
	Answered	**324**
	Skipped	**129**

4.2.4.5 Risk-Benefit Perception of Non-Thermal Emerging Food Processing

Table 4.14 and table 4.15 below summarized the main outcomes of this question for Non-Thermal Emerging Food Processing Technologies (Pulsed Electric Field (PEF), Ultrasound, and High PressureProcessing (HPP))

Respondents (N=364) stated more concerns about health, environment and unnaturalness issues regarding non-thermal emerging food processing technologies (55.77%, 24.18 % and 29.12% respectively). Approximately 22.80% of respondents indicated that they do not have any concern on these technologies.

In terms of benefits, consumers (N=323) mostly believe that non-thermal emerging food processing technologies improve yield of production, enhance food safety, and help to produce fresher products (19.81%, 18.89% and 14.24% respectively).

Table 4.14 Risk Perception of Non-Thermal Emerging Food Processing Technologies

Answer Choices	Responses	
Health concerns (Toxiological/biological concerns, allergenicity, unknown long term effects)	55.77%	203
long term effects etc)	2.75%	10
Environmental concerns	24.18%	88
Concerns on unnaturalness	29.12%	106
Animal welfare concerns	10.99%	40
Worker safety concerns	12.91%	47
Radioactivity	11.54%	42
No concern	22.80%	83
Other (please specify)	9.89%	36
	Answered	**364**
	Skipped	**89**

Table 4.15 Benefit Perception of Non-Thermal Emerging Food Processing Technologies.

Answer Choices	Responses	
Improve efficiency/yield of production	19.81%	64
Help country to compete/support of local economy	10.53%	34
Reduced pesticide use	10.22%	33
Enhanced food safety issues	18.89%	61
Result in fresher products, Better tasting/Enhanced flavour	14.24%	46
Result in more nutritious products	7.12%	23
Producing less waste	11.46%	37
None	41.18%	133
Other (please specify)	10.84%	35
	Answered	**323**
	Skipped	**130**

There were intriguing results in this section that low knowledge on the novel food processing technologies did not prevent consumers perceiving risks on these technologies. The percentages of the consumers who indicated that they did not heard about irradiation, nanotechnology, thermal and non-thermal novel technologies were 50.35%, 58%, 69.84% and 73.72% respectively. In spite of this high level of lack of knowledge; more than half of the respondents perceive health related risks from these technologies.

Siegrist and Cvetkovich (2000) argued that when consumers do not have detailed knowledge to assess risks and benefits associated with food processing technologies, they tend to rely on opinions of experts or authorities when forced to make risk assessments. However this study showed that consumers in Ireland can make direct assessments of risks and benefits and this does not depends on their level of knowledge and their trust level to governmental organisations. As it has stated in part 4.2.5 of this study, consumers in Ireland are trusting regulatory bodies but their level of risk perception was still high.

Perception of benefits and advantages of GMO, food irradiation and nanotechnology in Ireland are found to be weak, while the risks are found to be substantial. The reason of this may be insufficient understanding of these technologies; unknown and uncontrollable things generally provoke anxiety so that make consumers to feel concerned.

It is observed that there are high level of concerns on environmental, animal rights and worker safety issues. Consumers are becoming more and more conscious on these topics. Awareness on the irreversible harms to environment and nature is rising rapidly so before any new technology will be launched, communication on risk assessments

with consumers would be completed so that the consumers know about its sustainability and confidence about its effects on environment.

4.2.5 Acceptance&Trust

The Chi Square statistic is commonly used for testing relationships between categorical variables. It enables to evaluate Tests of Independence by using a crosstabulation that presents the distributions of two categorical variables simultaneously. The Test of Independence assesses whether a relationship exists between these two variables.

In SPSS Version 26, The Chi-Square statistic applied by requesting crosstabulation. The relationship between; "Trustworthiness of the organizations regarding providing right information and safe food products" and "Acceptance of novel food processing technologies" assessed by Pearson Chi-Square test.

4.4.5.1 Trustworthiness of Irish Governmental Organisation and acceptance of GMO.

Table 4.16 below indicates that there was a significant difference between trustworthiness of Irish Government with regards to acceptance of GMO since p value was less than 0.05 (x^2=53.287, df=20, p=.000). That means; there is an association between these two variables. If the consumers in Ireland trust the Irish government, they are more accepting the GMO.

Table 4.16 Cross tabulation results and chisquare test of trustworthiness of Irish governmental organisations and acceptance of GMO
(1) Totally Acceptable (2) Somewhat Acceptable (3) Neither Acceptable nor unacceptable (4) Somewhat Unacceptable (5) Totally Unacceptable.

Crosstab		Genetically Modified Food (GMO)					Total
		1	2	3	4	5	
Irish Governmental Organisations (working in food safety issues)		1	0	0	0	0	1
	Neither Trustworthy nor Untrustworthy	2	12	6	10	19	49
	Somewhat Trustworthy	9	37	21	46	60	173
	Somewhat Untrustworthy	1	3	6	4	13	27
	Very Trustworthy	9	27	6	23	7	72
	Very Untrustworthy	0	2	3	1	7	13
Total		22	81	42	84	106	335

Chi-Square Test	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	53.823a	20	.000
Likelihood Ratio	48.646	20	.000
N of Valid Cases	335		

a. 14 cells (46.7%) have expected count less than 5. The minimum expected count is .07.

4.4.5.2 Trustworthiness of Irish Governmental Organisation and acceptance of Irradiation.

According to table 4.17 below, significant difference exist between trustworthiness of Irish Government with regards to acceptance of Irradiation, since p value was less than 0.05 (x^2=51.063, df=20, p=.000). That means; there is an association between these two variables. If the consumers in Ireland trust the Irish government, they are more accepting the Irradiation technology.

Table 17 Cross tabulation and Chi-square results of trustworthiness of Irish governmental organisations and acceptance of Irradiation
(1) Totally Acceptable (2) Somewhat Acceptable (3) Neither Acceptable nor unacceptable (4) Somewhat Unacceptable (5) Totally Unacceptable

Crosstab		Irradiated Foods					
		1	2	3	4	5	Total
Irish Governmental Organisations (working in food safety issues)		0	1	0	0	0	1
	Neither Trustworthy nor Untrustworthy	0	5	20	7	14	46
	Somewhat Trustworthy	2	23	60	33	53	171
	Somewhat Untrustworthy	1	2	5	9	7	24
	Very Trustworthy	8	18	17	18	7	68
	Very Untrustworthy	0	1	4	2	6	13
Total		11	50	106	69	87	323

Chi-Square Test	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	51.063a	20	.000
Likelihood Ratio	47.592	20	.000
N of Valid Cases	323		

a. 14 cells (46.7%) have expected count less than 5. The minimum expected count is .03.

4.4.5.3 Trustworthiness of Irish Governmental Organisation and acceptance of Nanotechnology.

Table 4.18 indicates that there is a significant difference between trustworthiness of Irish Government with regards to acceptance of nanotechnology since p value was less than 0.05 (x^2=53.498, df=20, p=.000). If the consumers in Ireland trust the Irish government, they are more accepting nanotechnology.

Table 4.18 Cross tabulation and Chi-Square results of trustworthiness of Irish governmental organisations and acceptance of Nanotechnology (1)Totally Acceptable (2) Somewhat Acceptable (3) Neither Acceptable nor unacceptable (4) Somewhat Unacceptable (5) Totally Unacceptable

Crosstab		Nanotechnology					Total
		1	2	3	4	5	
Irish Governmental Organisations (working in food safety issues)		0	0	1	0	0	1
	Neither Trustworthy nor Untrustworthy	0	9	18	6	13	46
	Somewhat Trustworthy	5	35	70	30	30	170
	Somewhat Untrustworthy	0	4	5	9	6	24
	Very Trustworthy	11	20	23	12	3	69
	Very Untrustworthy	0	1	4	1	6	12
Total		16	69	121	58	58	322

Chi-Square Test	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	53.498a	20	.000
Likelihood Ratio	51.848	20	.000
N of Valid Cases	322		

a. 15 cells (50.0%) have expected count less than 5. The minimum expected count is .05.

4.4.5.4 Trustworthiness of Irish Governmental Organisation and Acceptance of Thermal Emerging Food Processing Technologies.

Table 4.19 indicates that there was a significant difference between trustworthiness of Irish Government with regards to acceptance of thermal emerging food processing technologies since p value was less than 0.05 (x^2=49.927, df=20, p=.000). That means; there is an association between these two variables. If the consumers in Ireland trust the Irish government, they are more accepting the technology.

Table 4.19 Crosstabulation and Chi-square results of trustworthiness of Irish governmental organisations and acceptance of Thermal Emerging Food Processing Technologies
(1) Totally Acceptable (2) Somewhat Acceptable (3) Neither Acceptable nor unacceptable (4) Somewhat Nonacceptable (5) Totally Unacceptable

Crosstab		Thermal Emerging Food Processing Technologies (Radio Frequency Heating and Ohmic Heating)					Total
		1	2	3	4	5	
Irish Governmental Organisations (working in food safety issues)		0	0	1	0	0	1
	Neither Trustworthy nor Untrustworthy	1	5	22	10	8	46
	Somewhat Trustworthy	10	36	68	32	24	170
	Somewhat Untrustworthy	1	0	10	6	8	25
	Very Trustworthy	17	10	27	11	4	69
	Very Untrustworthy	0	2	5	1	5	13
Total		29	53	133	60	49	324

Chi-Square Test	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	49.927a	20	.000
Likelihood Ratio	49.550	20	.000
N of Valid Cases	324		

a. 14 cells (46.7%) have expected count less than 5. The minimum expected count is .09.

4.4.5.5 Trustworthiness of Irish Governmental Organisation and Acceptance of Non-Thermal Emerging Food Processing Technologies.

According to table 4.20 there was a significant difference between trustworthiness of Irish Government with regards to acceptance of non-thermal emerging food processing technologies since p value was less than 0.05 (x^2=53.498, df=20, p=.000). That means; there is an association between these two variables. If the consumers in Ireland trust the Irish government, they are more accepting technology.

Table 4.20 Crosstabulation results of trustworthiness of Irish governmental organisations and acceptance of Non-Thermal Emerging Food Processing Technologies
(1)Totally Acceptable (2) Somewhat Acceptable (3) Neither Acceptable nor unacceptable (4) Somewhat Unacceptable (5) Totally Unacceptable

Crosstab		Non-Thermal Emerging Food Processing Technologies (Pulsed Electric Field (PEF), Ultrasound, High Pressure Processing (HPP))					Total
		1	2	3	4	5	
Irish Governmental Organisations (working in food safety issues)		0	0	1	0	0	1
	Neither Trustworthy nor Untrustworthy	3	3	22	8	9	45
	Somewhat Trustworthy	13	39	69	27	23	171
	Somewhat Untrustworthy	2	4	7	3	9	25
	Very Trustworthy	17	14	25	10	3	69
	Very Untrustworthy	1	2	3	2	5	13
Total		36	62	127	50	49	324

Chi-Square Test	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	42.661[a]	20	.002
Likelihood Ratio	40.392	20	.004
N of Valid Cases	324		

a. 13 cells (43.3%) have expected count less than 5. The minimum expected count is .11.

4.4.5.6 Other Organisations and Acceptance Relations

EU regulatory bodies, academic/health professionals, private food companies and media are also investigated in order to understand whether there is an association between trustworthiness and acceptance of emerging food processing technologies. The corresponding cross-tabulation tables and chi-square tests can be found in the Appendices part of this study. The results of these tests are summarized in the below table 4.21.

The p-values of the chi-square test less than 0.05 suggests that; if the consumers in Ireland trust the Irish government, EU regulatory bodies and academic researchers-health professionals, they are more accepting the technology. The test results indicates that there is no significant difference, that means no association found between trustworthiness of private food companies and media and acceptance of analysed food processing technologies.

Table 4.21 Chi-Square test results of other organisations and acceptance relations.

Chi-Square Test Results for Trustworthiness of EU Regulatory Bodies and Acceptance					
	GMO	**Irradiated Foods**	**Nanotechnology**	**Thermal Emerging Food Processing Technologies**	**Non-Thermal Emerging Food Processing Technologies**
Pearson Chi-Square	0.000	0.006	0.019	0.001	0.000
Valid N	335	323	322	324	324
Chi-Square Test Results for Trustworthiness of Academic Researches and Health Professionals and Acceptance					
	GMO	**Irradiated Foods**	**Nanotechnology**	**Thermal Emerging Food Processing Technologies**	**Non-Thermal Emerging Food Processing Technologies**
Pearson Chi-Square	0.003	0.010	0.011	0.002	0.000
Valid N	335	323	322	324	324

Chi-Square Test Results for Trustworthiness of Private Food Companies and Acceptance					
	GMO	**Irradiated Foods**	**Nanotechnology**	**Thermal Emerging Food Processing Technologies**	**Non-Thermal Emerging Food Processing Technologies**
Pearson Chi-Square	0.000	0.275	0.008	0.413	0.450
Valid N	335	323	322	324	324
Chi-Square Test Results for Trustworthiness of Media and Acceptance					
	GMO	**Irradiated Foods**	**Nanotechnology**	**Thermal Emerging Food Processing Technologies**	**Non-Thermal Emerging Food Processing Technologies**
Pearson Chi-Square	0.654	0.345	0.365	0.179	0.089
Valid N	335	323	322	324	324

The acceptance of emerging novel food processing technologies significantly influenced by trust in the system that produces and regulates it. It has been found that if the consumers are trusting Irish governmental organisations (working on food safety issues), EU Regulatory bodies and Academic Researches and Health Professionals, they are more accepting the technologies. Therefore, academic and industrial scientists, professional bodies, governments and consumer organisations must all play a role in communicating benefits and advantages of emerging novel food technologies to the public.

5. Conclusion, Limitations and Recommendation

5.1 Conclusion

The aim of this study was to investigate consumer attitudes towards emerging novel food processing technologies in Republic of Ireland. The success of any new food processing technology in marketplace depends on its acceptance in the public. Since food is a sensitive issue, studies on consumer attitudes towards foods should be investigated regularly. Communication is very important in informing consumers about the developments in science. In the highly competitive food industry, it is very important to listen to consumers and communicate with them very carefully. Wider involvement of the public in the earlier state of the development of the regulatory framework would facilitate consumer acceptance.

This study have shown that the majority of the consumers in Ireland have relatively little knowledge on the novel food technologies that are used in food production. GMO was an exception since 93.74% of the consumers in Ireland stated that they have an average knowledge on GMO. This percentage was much lower in other technologies because over the half of the respondents indicated that they did not heard about them. Uncertainty about concerns of the novel technologies for irradiation, nanotechnology, thermal and non-thermal emerging novel technologies were; 31.63%, 38.63%, 38.73% and 40.74% respectively. 4.63% of the consumers were uncertain about concerns caused by GMO while 46.34% of them are highly concerned on GMO applications in food. Reason of this negative sharp reaction in the use of GMO may be the continuous debates in the media over the decades. The media does not cover the topic of thermal and non-thermal emerging novel food processing technologies as much as they cover GMO or food irradiation.

Consumer segmentation analysis allowed to see that the higher percentage belong to segment labelled as “technological neutrals” (46.6%). “Technological enthusiasts” have

a percentage of only 17.7%. The change in the opinions of the consumers who are in the neutral segment, depend on the studies and communication efforts in the future. Consumer perceptions of risk and benefits are important determinants. Differences between the perception of food experts` and consumers should be studied.

It has seen from this study that, the consumers in Ireland have concerns on environmental and nature protection. Therefore, it is important to include environmental risk assessments as well as risk assessments on health issues while working on novel food processing technologies. The outcomes of these risk assessments should be shared and communicated with the public to ensure that they are aware of them. This is important not to repeat the mistakes in the biotechnology applications in food processing in the past.

5.2 Limitations and Recommendations

This study fulfilled its objectives, but it also has some limitations. Due to time and resources, limited responses could be collected. The researcher would have liked to collect more data with increased sample so that the validity would be increased. Although geographic limitations were aimed to overcome by distributing the survey to the community groups in Facebook and to community centres in different provinces, the majority of the respondents were from Dublin area (64.47%). In terms of method; only quantitative method is applied so some aspects such as emotions that affect perceptions could not be measured. Mixed-research method (both qualitative and quantitative) would be useful to investigate other aspects that affect perception of the consumers. Another limitations is; survey responses reflect the views and opinion of the participants and these responses are subject to change. This fact may be a limitation since consumer perception on novel food processing technologies may vary over time.

Forthcoming studies could be conducted on a larger scale in Ireland, having a larger sample size. In order to gain deeper understanding on the effect of ethical-psychological aspects, conducting qualitative analysis in Ireland would be useful. Studies including equal number of men and women to better understand gender reluctancy on food processing technologies would be useful.

Government authorities, food producers and media have a great responsibility in rising consumers` knowledge on novel technology issues. Consultation between scientists and consumers is an important issue that may have influence on perception. Therefore studies on communication issues should be taken further and great care should be taken systematically and effectively.

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APPENDIX

Appendix 1. Journal Article

Article for the Journal: Trends in Food Science and Technology

Title: Investigation of public attitudes to emerging novel food technologies in Republic of Ireland.

Authors: Emine Berna CIBIK, Amit K. Jaiswal, Anushree Priyadarshini

Abstract: This thesis addresses public attitudes towards emerging novel food technologies in Republic of Ireland. Quantitative data was collected through SurveyMonkey online survey software with a sample of 453 respondents. Consumer segmentation method was used to identify homogenous groups based on their responses on the novel food processing technologies. Three clusters were identified as; technological enthusiasts (17.7%), technological neutrals (46.6%) and technological sceptics (35.7%).

Five novel food processing technologies selected in this study as; Genetically Modified Organisms (GMO), Irradiation, Nanotechnology, Thermal Emerging Novel Food Processing Technologies and Non-Thermal Emerging Novel Food Processing Technologies. Consumer acceptance of these technologies is driven primarily by perceptions of risks, benefits, level of awareness and trust of several organisations. It is found that public trust in Irish governmental organisations, EU Regulatory bodies and academic/health professionals are significantly related to their acceptance of emerging novel food processing technologies.

Keywords: novel technologies; acceptance; consumers; Republic of Ireland

Introduction

Food is the basic need of humans and the main economic driver of the European Union (EU) (Galanakis, 2016). Food sector is consisting of many subsectors and growing rapidly. The global food retail market alone was estimated to be worth $5.8 trillion annually in 2014 (Marketline 2015, cited in Chaudhry 2017, p5). Like any other sector, food industry is also driven by innovation, competitiveness and profitability. The industry therefore always trying to develop new technologies to produce food products with improved taste, flavour, texture, longer shelf life, better safety, traceability and competitive costs (Chaudhry, 2017). Traditional processing methods like pasteurisation and sterilisation are also used to produce safe products by eliminating microorganisms but these processes can change natural taste and flavour of the food and also, they can destroy vitamins (Sun, 2005).

Food production is becoming more and more globalized, on the other hand public perceptions of quality and safety of foods are not same in different countries. For example, even in European Union (EU), consumer priorities and perceptions differ from country to country, some countries putting pesticides and animal welfare on the top of the priority list, while others think that genetically modified organisms are more worrying (Chaudhry, 2017).

Food is a very sensitive area, so consumers are particularly conservative while accepting and perceiving foods compared to other products. A new technological processing method must get away various societal and regulatory barriers before commercially applied (Chaudhry, 2017). Building consumer confidence and trust is very important since it determines failure or success of the novel food processing technology in the market.

There is extensive literature on consumer acceptance and perception of emerging novel food processing technologies in the world. The International Food Information Council (IFIC) conducted a survey in 2012 on "consumer perceptions of food technology". 750 adult consumers were surveyed in United States through online survey tool. According to the survey results; 69% of the participated consumers have confidence in U.S food supply and safety and the same majority (69%) of the consumers would likely buy foods improved through biotechnology.

In 2013, a survey conducted by Eurobarometer (European Commission 2013) to investigate European citizens` attitudes toward science and innovation in general. Data were collected from 27,563 respondents from member states. The results of this survey may be reflective of European consumers` attitudes toward innovative food processing methods. 75% respondents agree that science and technology have provided more opportunities for future generations. However, Europeans are concerned about the speed of change of science and technology have, and their potential for negative consequences: 62% think science makes their way of life change too quickly. Europeans expressed their concerns on risks to human health and the environment. 76% think that research and innovation should be conducted with giving attention to ethical principles and public involvement. According to this survey the source of information most Europeans rely on to learn about new developments in science and technology include television (65%), newspaper (33%), websites (32%), and magazines (26%).

Rollin et all (2011) investigated attitudes of consumers in Europe on 5 emerging food processing technologies; nanotechnology, genetic modification, nutrigenomics, food irradiation and animal cloning through the literature research. It is stated that; European consumers has a tendency to avoid risks and they demand transparency in the decision-making process of regulatory bodies. Taste found to be the most important factor for consumers that effect decision making process while purchasing food. Naturalness is

one of the important factor that affects purchase decision of consumer especially for nanotechnology food products. On the other hand, “price” found to be having limited importance in purchase decision process of consumers. It is stated that increased knowledge about food safety affects willingness to buy irradiated meat products. Acceptance of animal cloning technology of European consumers found to be low.

Frewer et all (2011) examined consumer acceptance of seven food processing technologies (GM Foods, Animal Cloning, Nutrigenomics, Nanotechnology, High Pressure Processing (HHP), Pulsed Electric Field (PEF)) by literature review. It is concluded from the research that in Europe, GM Foods and GM animals are mostly refused by the consumers. It is also found that, food irradiation is the technology which people perceived many risks. HHP and PEF are generally accepted technologies by the public because consumers perceive mainly benefits not risks with these technologies. On the other hand, awareness on nanotechnology in food processing found to be low.

Having reviewed the literature carefully, a lack of literature on perception of consumers on novel food technologies in Republic of Ireland is observed. Therefore, in order to contribute the literature accordingly, 2 objectives were identifies as;

- To investigate consumers’ awareness on novel food technologies,
- To define the similarities among the consumers’ perceptions by making cluster analysis.

Methodology

Quantitative research conducted via collecting data with online survey. Online self-completion mode was selected as a data collection method. SurveyMonkey (www.surveymonkey.com) online survey software program was used to design and disseminate survey link to the potential respondents in Ireland. The software also allowed to fill in the questionnaire by using mobile devices easily.

The first part was about sociodemographic characteristics of the respondents including; gender, age, education, place of residence and marital status.

In order to measure the awareness of the consumers; the following question for each 5 novel food processing technology was asked;

How much have you heard about…? The participants could mark their opinions as;

1) Nothing at all, 2-) A Little, 3-) Some, 4-) A lot.

Participants' trust rates to the organisations which have a role in food processing and marketing were measured by using 5-point scale; 1-) Very Trustworthy, 2-) Somewhat Trustworthy, 3-) Neither Trustworthy nor Untrustworthy, 4-) Somewhat Untrustworthy, 5-) Very Untrustworthy.

Respondents were asked how concerned they are about eating foods that had been processed by each novel food processing technology. They could indicate their level of concern by a 5-point scale; 1) No concern, 2) Slight Concern, 3) Moderate Concern, 4) High Concern, 5) Uncertain.

The respondents presented their perceptions of risk and benefits on the five novel food processing technologies.

The level of acceptance of each technology were measured by using 5-point scale; 1) Totally Acceptable, 2) Somewhat Acceptable, 3) Neither Acceptable nor Unacceptable, 4) Somewhat Unacceptable, 5) Totally Unacceptable.

The potential respondents were invited by the web-link via e-mail, Facebook , Linked-in and Instagram. While sending the survey web-link; the purpose and scope of the research were explained. The targeted participants were all consumers who are living in Ireland (18 years old or above). The survey software allowed to store the collected data on the website which can be reached by the individual account. It also allowed to download the data in excel format in order to use it in data analysis in SPSS.

Data Analysis

Total response rate of this study was 453. The following statistical methods were used in data analysis;

- Descriptive Statistics
  - Frequency Distribution; one variable is considered at a time. The objective is to obtain a count of a number of responses associated with different values of the variable (Malhotra, 2020).

- Consumer Segmentation/Cluster Analysis
  - The primary objective of cluster analysis is to classify responses into relatively homogenous groups based on the set of variables (Malhotra. 2020).

Data analysis were performed by using IBM SPSS Statistics Version 26.

Results

Awareness of the Consumers on Emerging Novel Food Processing Technologies

Tablo 1. Percent of (N=431) respondents that heard nothing about novel food processing technologies.

Food Processing Technology	% Response of "I heard nothing about this technology"
GMO	6.26
Irradiation	50.35
Nanotechnology	58.00
Thermal Emerging Food Processing Technologies (Radio Frequency Heating and Ohmic Heating)	69.84
Non-Thermal Emerging Food Processing Technologies (Pulsed Electric Field (PEF), Ultrasound, High Pressure Processing (HPP)	73.72

It can be seen in table 1 that majority have lack of knowledge (on emerging novel food processing technologies except GMO, only 6.26 of the participants indicated that they are unfamiliar with GMO.

Table 2 Percent of (n=410) respondents that were "Highly Concerned" and "Uncertain" about the foods processed by novel technologies.

Food Processing Technology	% Highly Concerned	% Uncertain
GMO	46.34	4.63
Irradiation	29.20	31.63
Nanotechnology	20.54	38.63
Thermal Emerging Food Processing Technologies (Radio Frequency Heating and Ohmic Heating)	17.65	38.73
Non-Thermal Emerging Food Processing Technologies (Pulsed Electric Field (PEF), Ultrasound, High Pressure Processing (HPP)	14.32	40.74

As seen in table 2, genetic modification and irradiation of foods evoked the most concern among the consumers (46.34% and 29.20% of respondents, respectively, were highly concerned with foods processed with these technologies). Thermal Emerging

Food Processing Technologies (17.65%) and Non-Thermal Emerging Food Processing Technologies (14.32%) generated significantly less concern.

Cluster Analysis

305 responses were valid and used in cluster analysis.3 clusters were identified based on the responses to questions on the level of awareness, acceptance and concerns. Tas can be seen in table 3 these clusters were as follows;

Cluster I. Technology Enthusiasts

Cluster II. Technology Neutral

Cluster III. Technology Sceptics

Table 3. Cluster Analysis

Hierarcial Cluster Analysis by Ward Method					
		Frequency	**Percent**	**Valid Percent**	**Cumulative Percent**
Valid	Cluster 1	54	11,9	**17,7**	17,7
	Cluster 2	142	31,3	**46,6**	64,3
	Cluster 3	109	24,1	**35,7**	100,0
	Total	305	67,3	100,0	
Missing	System	148	32,7		
Total		453	100,0		

Regarding the demographic characteristics of the respondents in cluster analysis (Valid N=305), the sample consists of more females than males. Most of the respondents (68.2%) were living in City/Town in Ireland. Respondents' education level was good as 78.68% of them completed graduate and postgraduate education. The detailed description of the sample, including socioeconomic characteristics, is summarized in Table 4.

Tablo 4 Demographic profile of the consumers in cluster analysis.

Variables	Total Sample (N:305)	Cluster 1. Technology Enthusiasts (Frq*) (N:54)	Cluster 1. Technology Enthusiasts (%)	Cluster 2. Technology Neutral (Frq*) (N:142)	Clluster 2. Technology Neutral (%)	Cluster 3. Technology Sceptics (Frq*) (N:109)	Cluster 3. Technology Sceptics (%)
Place of Residence							
City/Town	208	39	72,2	95	66,9	74	67,9
Countryside	97	15	27,8	47	33,1	35	32,1
Gender							
Female	218	30	55,6	100	70,4	88	80,7
Male	84	24	44,4	41	28,9	19	17,4
Other	3	0		1	0,7	2	1,8
Age							
18 to 25 years old	30	8	14,8	20	14,1	2	1,8
26 to 35 years old	88	18	33,3	41	28,9	29	26,6
36 to 50 years old	115	24	44,4	44	31	47	43,1
51 and above	72	4	7,4	37	26,1	31	28,4
Level of Education							
Secondary or less	30	0		20	14,1	10	9,2
High School Graduate	35	4	7,4	15	10,6	16	14,7
Graduate Education (eg: BSc, BSE, BA)	147	23	42,6	67	47,2	57	52,3
Postgraduate Education (eg: PhD, MSc, MA)	93	27	50	40	28,2	26	23,9

Marital Status							
Single	87	21	38,9	48	33,8	18	16,5
Married	188	28	51,9	80	56,3	80	73,4
Other	29	5	9,3	14	9,9	10	9,2
Have you ever worked or studied in food processing related area?							
Yes	83	38	70,4	28	19,7	17	15,6
No	221	16	29,6	114	80,3	91	83,5

Cluster I. Technology Enthusiasts

This segment consists of consumers who have favourable attitudes toward novel food processing technologies. The socio demographic profile of technology enthusiasts is composed of consumers with high education level. 42,6% of them completed graduate education and 50% of them completed postgraduate education. In terms of age, 14,8% were between 18 to 25 years old, 33.3% were between 26 to 35 years old and 44,4% were between 36 to 50 years old. When compared to other clusters, the respondents in this group have mostly (70.4%) worked or studied in food processing related area. Consumers in this segment have higher level of awareness on emerging food processing technologies and are mostly willing to buy food products that were processed with these technologies. They expressed considerable optimism regarding the commercialization of novel food processing technologies.

Cluster II. Technology Neutral

This segment consists of consumers who have neutral attitudes toward novel food processing technologies. As seen in table 2, demographic profile of technology neutral segment is mainly middle-aged females with higher education. They are uncertain about the concerns on these technologies and could not be able to express a specific response to acceptance question.

Cluster III. Technology Sceptics

The respondents from this segment presented negative opinions on novel food processing technologies. This segment composed of mostly females (80.7%). 43.1% were between 36 to 50 years old and 73.4% were married. Only 15.6% of these group have some study or work experience in food processing area. When compared with Technology Enthusiasts and Technology Neutral segments, those consumers have higher level of concerns on emerging novel food processing technologies and they find them mostly unacceptable. Lack of knowledge among consumers in this segment contributed to consumers` sceptism to these technologies.

Discussion

Public awareness found to be lower in irradiation, nanotechnology, thermal and non-thermal emerging novel food processing. Most of the respondents stated that they have not heard about them (50.35% for irradiation, 58% for nanotechnology, 69.84% for thermal novel technologies and 73.72% Non-thermal novel technologies. However, low public awareness do not prevent consumers from perceiving risks and benefits towards these technologies.

A sharp negative reaction was observed in the use of GMO and irradiation in food production among consumers in Ireland (46.34% (GMO) and 29.20% (Irradiation) of 410 consumers were highly concerned). The majority of the participants stated that they have average knowledge on GMO. But in the case of GMO; increased public knowledge does not always make it easy to accept the technology. The information that public have should be reliable and correct. Therefore, problem is not just poor knowledge in these technologies, it is necessary to analyse the causes of rejection of GMO and irradiation deeper. The differences between expert and public risk perceptions should be seen as the difference in socio-ethical perspective. Scientists have a tendency to only focus on the risk associated with specific biological and medical

hazards while the public also have concerns about social, ethical and ecological factors. For consumer acceptance of the technologies and the food products produced from them, all aspects of public concerns must be addressed.

Most consumers in Ireland gain information about new food processing technologies from internet (46.04%), social networks (27.23%), and television (24.50%). The key source of information used by consumers are the media so the media play a significant role in the providing information. Public tend to believe what they read or see in media and their views are strongly affected by it.

Providing more information about these technologies seem to be key to increase consumer acceptance. This is especially important in the case of irradiation and nanotechnology processing since many consumers associate the technology name with hazards and are sceptical about possible side effects. It would be useful to provide information about the processing technologies described on the package, allowing the consumer to recognize the advantages of these products.

The overwhelming majority customers in Cluster I (Technology Enthusiasts) had higher education level (92.6%-graduate and postgraduate education), so the individuals with more formal education are more accepting the technologies. Therefore, education of the next generation customers is equally important and would be more effective that short-term communication efforts with adult consumers.

Conclusion

The aim of this study was to investigate consumer attitudes towards emerging novel food processing technologies in Republic of Ireland. The success of any new food processing technology in marketplace depends on its acceptance in the public. Since food is a sensitive issue, studies on consumer attitudes towards foods should be investigated regularly. Communication is very important in informing consumers about the developments in science. In the highly competitive food industry, it is very important to listen to consumers and communicate with them very carefully. Wider involvement of the public in the earlier state of the development of the regulatory framework would facilitate consumer acceptance.

This study have shown that the majority of the consumers in Ireland have relatively little knowledge on the novel food technologies that are used in food production. GMO was an exception since 93.74% of the consumers in Ireland stated that they have an average knowledge on GMO. This percentage was much lower in other technologies because over the half of the respondents indicated that they did not heard about them. Uncertainty about concerns of the novel technologies for irradiation, nanotechnology, thermal and non-thermal emerging novel technologies were; 31.63%, 38.63%, 38.73% and 40.74% respectively. 4.63% of the consumers were uncertain about concerns caused by GMO while 46.34% of them are highly concerned on GMO applications in food. Reason of this negative sharp reaction in the use of GMO may be the continuous debates in the media over the decades. The media does not cover the topic of thermal and non-thermal emerging novel food processing technologies as much as they cover GMO or food irradiation.

Consumer segmentation analysis allowed to see that the higher percentage belong to segment labelled as “technological neutrals” (46.6%). “Technological enthusiasts” have

a percentage of only 17.7%. The change in the opinions of the consumers who are in the neutral segment, depend on the studies and communication efforts in the future. Consumer perceptions of risk and benefits are important determinants. Differences between the perception of food experts` and consumers should be studied.

Recommendation

Forthcoming studies could be conducted on a larger scale in Ireland, having a larger sample size. In order to gain deeper understanding on the effect of ethical-psychological aspects, conducting qualitative analysis in Ireland would be useful. Studies including equal number of men and women to better understand gender reluctancy on food processing technologies would be useful.

Government authorities, food producers and media have a great responsibility in rising consumers` knowledge on novel technology issues. Consultation between scientists and consumers is an important issue that may have influence on perception. Therefore studies on communication issues should be taken further and great care should be taken systematically and effectively.

Appendix 2.Survey Questionaire

Survey: Investigation of public attitudes towards emerging novel food technologies in Republic of Ireland.

The food industry is currently interested in a wide range of novel food production and processing technologies in order to produce economical and improved quality food products. Consumer acceptance of these new technologies can greatly influence their success in marketplace. This survey is designed to investigate consumer awareness, perceived risks and benefits of new food processing technologies in Republic of Ireland. This questionnaire will provide researchers some information and data on Irish consumer perceptions and acceptance on emerging novel food technologies and this will help to have a better understanding of public attitudes to these technologies.

This survey is in part of the Masters in Food Safety Management programme at Technological University Dublin, Ireland. If you decide to take part in this study, all information will be treated with strict confidentiality. The survey doesn't ask for any information which can identify the respondent. However, in order to reduce the risk of any person being identified during the research, the data would be anonymised prior to the data analysis; I appreciate your help and participation.

Part I. Socio Demographic Profile

Q1. Residence

- I live in Ireland
- I do not live in Ireland

Q2. Place of Residence

- Countryside
- City/Town

Q3. Gender

- Male
- Female
- Other

Q4. Age

- 18 to 25 years old
- 26 to 35 years old
- 36 to 50 years old
- 51 and above

Q5. Level of Education

- Secondary or less
- High School Graduate
- Graduate Education (eg: BSc, BSE, BA)
- Postgraduate Education (eg: PhD, MSc, MA)

Q6. Marital Status

- Single
- Married
- Other

Q7. Have you ever worked or studied on food processing related area?

- Yes
- No

Part II.Awareness

Q7. How much have you heard about Genetically Modified Food (GMO) before?

- Nothing at all
- A little
- Some
- A lot

Q8.How much have you heard about Irradiated Foods before?

- Nothing at all
- A little
- Some
- A lot

Q9.How much have you heard about Nanotechnology in Food Processing before?

- Nothing at all
- A little
- Some
- A lot

Q10.How much have you heard about Thermal Emerging Food Processing Technologies (Radio Frequency Heating and Ohmic Heating) before?

- Nothing at all
- A little
- Some
- A lot

Q11. Non-Thermal Emerging Food Processing Technologies(Pulsed Electric Field (PEF), Ultrasound, High Pressure Processing (HPP))before?

- Nothing at all
- A little
- Some
- A lot

Q12. Where have you heard of these technologies?(You can mark more than one)

- Television
- Internet
- Social Networks
- Newspaper
- School/University
- From friends or family
- Never heard about these
- Others, please specify…….

In your opinion, please rate trustworthiness of the following organizations regarding providing right information and safe food products to the market?

Q13. Irish Governmental Organisations (working in food safety issues)

- o Very Trustworthy
- o Somewhat Trustworthy
- o Neither Trustworthy nor Untrustworthy
- o Somewhat Untrustworthy
- o Very Untrustworthy

Q14. EU Regulatory Bodies

- o Very Trustworthy
- o Somewhat Trustworthy
- o Neither Trustworthy nor Untrustworthy
- o Somewhat Untrustworthy
- o Very Untrustworthy

Q15. Academic Researches and Health Professionals

- o Very Trustworthy
- o Somewhat Trustworthy
- o Neither Trustworthy nor Untrustworthy
- o Somewhat Untrustworthy
- o Very Untrustworthy

Q16. Private Food Companies

- o Very Trustworthy
- o Somewhat Trustworthy
- o Neither Trustworthy Nor Untrustworthy

- Somewhat Untrustworthy
- Very Untrustworthy

Q16. Media

- Very Trustworthy
- Somewhat Trustworthy
- Neither Trustworthy Nor Untrustworthy
- Somewhat Untrustworthy
- Very Untrustworthy

Part III Risk and Benefit Perception

Please indicate how concerned you are about eating foods that had been processed by each technology;

Q17. Genetically Modified Food (GMO)

- No Concern
- Slight Concern
- Moderate Concern
- High Concern
- Uncertain

Q18. Irradiated Foods

- No Concern
- Slight Concern
- Moderate Concern
- High Concern
- Uncertain

Q19. Nanotechnology

- No Concern
- Slight Concern
- Moderate Concern
- High Concern
- Uncertain

Q20.Thermal Emerging Food Processing Technologies (Radio Frequency Heating and Ohmic Heating)

- No Concern
- Slight Concern
- Moderate Concern
- High Concern
- Uncertain

Q21.Non-Thermal Emerging Food Processing Technologies(Pulsed Electric Field (PEF), Ultrasound, High Pressure Processing (HPP))

- No Concern
- Slight Concern
- Moderate Concern
- High Concern
- Uncertain

Please mark the followings concerns that you think are related with the listed novel food technologies (You can mark more than one)

Q22. Genetically Modified Food (GMO)

- Health concerns(Toxiological/biological concerns, allergenicity, unknown long term effects etc)
- Environmental concerns
- Concerns on unnaturalness
- Animal welfare concerns
- Worker safety concerns
- Radioactivity
- No concern
- Other, please specify

Q23. Irradiated Foods

- Health concerns(Toxiological/biological concerns, allergenicity, unknown long term effects etc)
- Environmental concerns
- Concerns on unnaturalness
- Animal welfare concerns
- Worker safety concerns
- Radioactivity
- No concern
- Other, please specify

Q24. Nanotechnology

- Health concerns(Toxiological/biological concerns, allergenicity, unknown long term effects etc)
- Environmental concerns
- Concerns on unnaturalness
- Animal welfare concerns

- Worker safety concerns
- Radioactivity
- No concern
- Other, please specify

Q25. Thermal Emerging Food Processing Technologies (Radio Frequency Heating and Ohmic Heating)

- Health concerns(Toxiological/biological concerns, allergenicity, unknown long term effects etc)
- Environmental concerns
- Concerns on unnaturalness
- Animal welfare concerns
- Worker safety concerns
- Radioactivity
- No concern
- Other, please specify

Q26. Non-Thermal Emerging Food Processing Technologies(Pulsed Electric Field (PEF), Ultrasound, High Pressure Processing (HPP))

- Health concerns(Toxiological/biological concerns, allergenicity, unknown long term effects etc)
- Environmental concerns
- Concerns on unnaturalness
- Animal welfare concerns
- Worker safety concerns
- Radioactivity
- No concern

- Other, please specify

Please mark the following benefits that you think are related with the listed novel food technologies (You can mark more than one);

Q27.Genetically Modified Food (GMO)

- Improve efficiency/yield of production
- Help country to compete/support of local economy
- Reduced pesticide use
- Enhanced food safety issues
- Result in fresher products, Better tasting/Enhanced flavour
- Result in more nutritious products
- Producing less waste
- None
- Other, please specify

Q28. Irradiated Foods

- Improve efficiency/yield of production
- Help country to compete/support of local economy
- Reduced pesticide use
- Enhanced food safety issues
- Result in fresher products, Better tasting/Enhanced flavour
- Result in more nutritious products
- Producing less waste
- None
- Other, please specify

Q29. Nanotechnology

- Improve efficiency/yield of production
- Help country to compete/support of local economy
- Reduced pesticide use
- Enhanced food safety issues
- Result in fresher products, Better tasting/Enhanced flavour
- Result in more nutritious products
- Producing less waste
- None
- Other, please specify

Q30.Thermal Emerging Food Processing Technologies (Radio Frequency Heating and Ohmic Heating)

- Improve efficiency/yield of production
- Help country to compete/support of local economy
- Reduced pesticide use
- Enhanced food safety issues
- Result in fresher products, Better tasting/Enhanced flavour
- Result in more nutritious products
- Producing less waste
- None
- Other, please specify

Q31.Non-Thermal Emerging Food Processing Technologies(Pulsed Electric Field (PEF), Ultrasound, High Pressure Processing (HPP))

- Improve efficiency/yield of production
- Help country to compete/support of local economy
- Reduced pesticide use

- Enhanced food safety issues
- Result in fresher products, Better tasting/Enhanced flavour
- Result in more nutritious products
- Producing less waste
- None
- Other, please specify

Part VI. Willingness to try foods produced by new unconventional technologies

Q32. Are you likely to buy a food product which has been processed by a novel or emerging food technology?

- Yes
- No
- Not sure

Q33. If you answered yes to the above question (Q32), please indicate which type of novel or emerging food technology you would most prefer your food to be processed by (You can mark more than one).

- Genetically Modified Foods
- Irradiated Foods
- Nanotechnology
- Thermal Emerging Food Processing Technologies (Radio Frequency Heating and Ohmic Heating)
- Non-Thermal Emerging Food Processing Technologies (Pulsed Electric Field (PEF), Ultrasound, High Pressure Processing (HPP), etc)

Part V. Acceptance

Please mark your level of acceptance of the following food production technologies.

Q34. Genetically Modified Food (GMO)

- Totally Acceptable
- Somewhat Acceptable
- Neither Acceptable nor unacceptable
- Somewhat Unacceptable
- Totally Unacceptable

Q35. Irradiated Foods

- Totally Acceptable
- Somewhat Acceptable
- Neither Acceptable nor unacceptable
- Somewhat Unacceptable
- Totally Unacceptable

Q36. Nanotechnology

- Totally Acceptable
- Somewhat Acceptable
- Neither Acceptable nor unacceptable
- Somewhat Unacceptable
- Totally Unacceptable

Q37. Thermal Emerging Food Processing Technologies (Radio Frequency Heating and Ohmic Heating)

- Totally Acceptable
- Somewhat Acceptable
- Neither Acceptable nor unacceptable
- Somewhat Unacceptable

- Totally Unacceptable

Q38. Non-Thermal Emerging Food Processing Technologies (Pulsed Electric Field (PEF), Ultrasound, High Pressure Processing (HPP))

- Totally Acceptable
- Somewhat Acceptable
- Neither Acceptable nor unacceptable
- Somewhat Unacceptable
- Totally Unacceptable

Q 41. Nationality

- Irish
- Other…..

Q 42. Which Irish provinces you live in?

- Connacht (Galway, Leitrim, Mayo, Roscommon and Sligo).
- Leinster (Carlow, Dublin, Kildare, Kilkenny, Laois, Longford, Louth, Meath, Offaly, Westmeath, Wexford and Wicklow)
- Munster (Clare, Cork, Kerry, Limerick, Tipperary and Waterford)
- Ulster (Antrim, Armagh, Cavan, Donegal, Down, Fermanagh, Londonderry, Monaghan and Tyrone).

Appendix 3. Agglomeration Schedule-Wards Cluster Analysis

Agglomeration Schedule

Stage	Cluster Combined		Coefficients	Stage Cluster First Appears		Next Stage
	Cluster 1	Cluster 2		Cluster 1	Cluster 2	
1	90	268	.000	0	0	58
2	24	261	.000	0	0	16
3	6	211	.000	0	0	27
4	73	204	.000	0	0	85
5	42	200	.000	0	0	50
6	103	180	.000	0	0	27
7	105	178	.000	0	0	18
8	113	141	.000	0	0	24
9	86	119	.000	0	0	133
10	16	102	.000	0	0	19
11	33	101	.000	0	0	17
12	36	97	.263	0	0	55
13	173	215	.540	0	0	60
14	38	56	.817	0	0	139
15	75	220	1.178	0	0	32
16	24	247	1.548	2	0	39
17	33	138	1.918	11	0	43
18	105	117	2.287	7	0	48
19	16	95	2.657	10	0	187
20	124	278	3.037	0	0	47

21	13	236	3.417	0	0	188
22	92	265	3.807	0	0	40
23	25	142	4.197	0	0	76
24	89	113	4.590	0	8	58
25	67	281	5.062	0	0	64
26	134	148	5.534	0	0	59
27	6	103	6.088	3	6	60
28	27	301	6.660	0	0	98
29	30	87	7.231	0	0	37
30	115	165	7.821	0	0	97
31	68	185	8.489	0	0	41
32	75	83	9.161	15	0	63
33	156	273	9.851	0	0	74
34	4	99	10.542	0	0	52
35	79	81	11.233	0	0	163
36	80	203	11.929	0	0	155
37	30	88	12.626	29	0	273
38	107	241	13.375	0	0	99
39	24	287	14.129	16	0	109
40	92	155	14.888	22	0	100
41	66	68	15.662	0	31	138
42	144	260	16.455	0	0	136
43	15	33	17.260	0	17	177
44	60	94	18.095	0	0	73
45	31	253	18.980	0	0	132

46	223	224	19.865	0	0	230
47	124	154	20.754	20	0	61
48	100	105	21.647	0	18	75
49	205	291	22.566	0	0	80
50	42	199	23.494	5	0	100
51	5	44	24.456	0	0	153
52	4	14	25.425	34	0	103
53	34	240	26.398	0	0	95
54	40	64	27.388	0	0	83
55	36	85	28.404	12	0	126
56	167	294	29.439	0	0	93
57	3	23	30.491	0	0	79
58	89	90	31.561	24	1	78
59	47	134	32.646	0	26	107
60	6	173	33.749	27	13	201
61	124	258	34.856	47	0	155
62	7	118	35.965	0	0	131
63	75	192	37.080	32	0	188
64	67	271	38.197	25	0	185
65	194	239	39.365	0	0	125
66	98	108	40.532	0	0	166
67	129	269	41.712	0	0	122
68	280	283	42.893	0	0	129
69	153	231	44.075	0	0	138
70	55	255	45.261	0	0	119

71	127	228	46.453	0	0	128
72	143	145	47.645	0	0	158
73	60	207	48.851	44	0	121
74	156	196	50.069	33	0	136
75	100	209	51.340	48	0	115
76	18	25	52.612	0	23	210
77	164	234	53.900	0	0	164
78	89	210	55.189	58	0	246
79	3	125	56.500	57	0	163
80	59	205	57.878	0	49	141
81	82	120	59.323	0	0	133
82	11	169	60.771	0	0	150
83	40	110	62.237	54	0	139
84	32	197	63.704	0	0	179
85	73	166	65.183	4	0	177
86	139	158	66.670	0	0	112
87	184	216	68.159	0	0	151
88	29	69	69.668	0	0	149
89	77	182	71.191	0	0	128
90	52	160	72.748	0	0	178
91	50	136	74.306	0	0	142
92	221	267	75.883	0	0	185
93	10	167	77.535	0	56	154
94	74	295	79.189	0	0	129
95	34	179	80.867	53	0	113

96	218	300	82.573	0	0	159
97	61	115	84.318	0	30	114
98	27	187	86.065	28	0	202
99	107	193	87.823	38	0	244
100	42	92	89.583	50	40	187
101	37	51	91.410	0	0	195
102	49	62	93.276	0	0	121
103	4	130	95.165	52	0	193
104	78	285	97.080	0	0	145
105	147	150	99.004	0	0	238
106	235	251	100.938	0	0	227
107	47	242	102.895	59	0	116
108	126	298	104.911	0	0	127
109	24	246	106.942	39	0	150
110	111	186	108.985	0	0	167
111	58	132	111.045	0	0	233
112	96	139	113.130	0	86	255
113	34	137	115.237	95	0	153
114	8	61	117.347	0	97	221
115	100	152	119.472	75	0	203
116	47	157	121.654	107	0	140
117	53	104	123.882	0	0	156
118	21	151	126.135	0	0	217
119	55	238	128.410	70	0	194
120	227	232	130.688	0	0	161

121	49	60	132.984	102	73	209
122	129	276	135.289	67	0	134
123	135	191	137.671	0	0	180
124	54	171	140.075	0	0	223
125	123	194	142.574	0	65	234
126	28	36	145.137	0	55	154
127	2	126	147.715	0	108	249
128	77	127	150.299	89	71	214
129	74	280	152.906	94	68	236
130	175	217	155.518	0	0	247
131	7	17	158.139	62	0	203
132	31	245	160.794	45	0	178
133	82	86	163.453	81	9	174
134	129	296	166.117	122	0	242
135	63	72	168.787	0	0	225
136	144	156	171.491	42	74	217
137	112	288	174.238	0	0	183
138	66	153	177.074	41	69	208
139	38	40	179.962	14	83	202
140	20	47	182.900	0	116	208
141	22	59	185.846	0	80	212
142	50	257	188.801	91	0	237
143	1	9	191.769	0	0	199
144	177	284	194.818	0	0	209
145	78	128	197.878	104	0	229

146	131	201	200.973	0	0	184
147	106	140	204.106	0	0	182
148	114	206	207.250	0	0	168
149	29	41	210.404	88	0	227
150	11	24	213.576	82	109	215
151	184	290	216.757	87	0	170
152	190	237	219.963	0	0	205
153	5	34	223.232	51	113	214
154	10	28	226.562	93	126	252
155	80	124	229.893	36	61	220
156	53	213	233.266	117	0	194
157	289	293	236.648	0	0	196
158	143	214	240.036	72	0	218
159	218	263	243.444	96	0	215
160	48	71	246.880	0	0	190
161	12	227	250.382	0	120	246
162	198	248	253.949	0	0	224
163	3	79	257.530	79	35	235
164	163	164	261.118	0	77	240
165	259	277	264.732	0	0	186
166	98	109	268.402	66	0	236
167	91	111	272.125	0	110	244
168	114	159	275.881	148	0	184
169	233	292	279.648	0	0	198
170	184	222	283.419	151	0	204

171	57	76	287.229	0	0	275
172	168	256	291.076	0	0	219
173	93	264	294.985	0	0	220
174	70	82	298.952	0	133	201
175	244	275	302.955	0	0	207
176	116	149	307.010	0	0	221
177	15	73	311.066	43	85	243
178	31	52	315.167	132	90	255
179	32	304	319.314	84	0	241
180	135	270	323.471	123	0	225
181	65	226	327.640	0	0	251
182	106	181	331.813	147	0	265
183	112	250	335.995	137	0	251
184	114	131	340.224	168	146	229
185	67	221	344.641	64	92	248
186	259	272	349.291	165	0	238
187	16	42	354.081	19	100	259
188	13	75	358.880	21	63	243
189	229	262	363.811	0	0	239
190	46	48	368.991	0	160	213
191	84	254	374.170	0	0	250
192	302	305	379.419	0	0	257
193	4	172	384.744	103	0	256
194	53	55	390.074	156	119	260
195	37	225	395.522	101	0	226

196	43	289	401.073	0	157	230
197	202	282	406.633	0	0	278
198	183	233	412.195	0	169	266
199	1	26	417.768	143	0	261
200	174	176	423.428	0	0	267
201	6	70	429.221	60	174	235
202	27	38	435.050	98	139	216
203	7	100	440.883	131	115	232
204	184	274	446.766	170	0	253
205	121	190	452.660	0	152	240
206	279	286	458.575	0	0	226
207	244	252	464.516	175	0	228
208	20	66	470.551	140	138	276
209	49	177	476.754	121	144	286
210	18	122	483.014	76	0	247
211	35	243	489.288	0	0	262
212	22	230	495.668	141	0	266
213	39	46	502.143	0	190	234
214	5	77	508.644	153	128	258
215	11	218	515.207	150	159	259
216	27	189	521.849	202	0	270
217	21	144	528.532	118	136	250
218	143	266	535.297	158	0	242
219	45	168	542.113	0	172	274
220	80	93	549.000	155	173	256

221	8	116	556.118	114	176	254
222	161	299	563.348	0	0	265
223	54	146	570.580	124	0	269
224	162	198	577.818	0	162	237
225	63	135	585.082	135	180	279
226	37	279	592.464	195	206	271
227	29	235	599.998	149	106	257
228	19	244	607.619	0	207	263
229	78	114	615.299	145	184	260
230	43	223	623.063	196	46	281
231	195	212	630.948	0	0	285
232	7	208	639.025	203	0	277
233	58	303	647.292	111	0	267
234	39	123	655.560	213	125	248
235	3	6	663.954	163	201	270
236	74	98	672.397	129	166	254
237	50	162	681.193	142	224	245
238	147	259	690.209	105	186	263
239	170	229	699.243	0	189	268
240	121	163	708.458	205	164	268
241	32	188	717.697	179	0	264
242	129	143	727.032	134	218	274
243	13	15	736.660	188	177	252
244	91	107	746.380	167	99	258
245	50	133	756.205	237	0	281

246	12	89	766.095	161	78	280
247	18	175	776.144	210	130	261
248	39	67	786.438	234	185	278
249	2	219	796.995	127	0	282
250	21	84	808.064	217	191	273
251	65	112	819.218	181	183	283
252	10	13	830.468	154	243	276
253	184	249	842.054	204	0	262
254	8	74	853.761	221	236	279
255	31	96	865.734	178	112	269
256	4	80	878.042	193	220	264
257	29	302	890.385	227	192	299
258	5	91	902.730	214	244	272
259	11	16	915.874	215	187	290
260	53	78	929.475	194	229	292
261	1	18	943.315	199	247	291
262	35	184	957.585	211	253	272
263	19	147	971.991	228	238	282
264	4	32	986.661	256	241	288
265	106	161	1001.438	182	222	275
266	22	183	1016.887	212	198	290
267	58	174	1032.910	233	200	283
268	121	170	1050.404	240	239	293
269	31	54	1068.072	255	223	295
270	3	27	1086.822	235	216	277

271	37	297	1105.887	226	0	285
272	5	35	1125.384	258	262	286
273	21	30	1144.967	250	37	284
274	45	129	1164.774	219	242	292
275	57	106	1185.733	171	265	284
276	10	20	1207.180	252	208	288
277	3	7	1230.173	270	232	294
278	39	202	1253.673	248	197	280
279	8	63	1277.364	254	225	293
280	12	39	1302.356	246	278	295
281	43	50	1327.761	230	245	287
282	2	19	1353.707	249	263	291
283	58	65	1380.276	267	251	287
284	21	57	1408.840	273	275	297
285	37	195	1437.513	271	231	289
286	5	49	1468.431	272	209	289
287	43	58	1503.731	281	283	296
288	4	10	1540.894	264	276	300
289	5	37	1579.501	286	285	296
290	11	22	1618.996	259	266	294
291	1	2	1664.639	261	282	299
292	45	53	1722.187	274	260	301
293	8	121	1781.606	279	268	298
294	3	11	1850.863	277	290	297
295	12	31	1924.045	280	269	298

296	5	43	2001.061	289	287	302
297	3	21	2079.503	294	284	302
298	8	12	2172.736	293	295	300
299	1	29	2268.168	291	257	301
300	4	8	2403.874	288	298	303
301	1	45	2662.416	299	292	304
302	3	5	2954.562	297	296	303
303	3	4	3484.877	302	300	304
304	1	3	4560.000	301	303	0

Appendix 4. Crosstabulation and Chi-Square Test

Cross-tabulation and Chi-Square results of trustworthiness of EU Regulatory Bodies and acceptance of GMO (1) Totally Acceptable (2) Somewhat Acceptable (3) Neither Acceptable nor unacceptable (4) Somewhat Unacceptable (5) Totally Unacceptable.

		Genetically Modified Food (GMO)					
		1	2	3	4	5	Total
EU Regulatory Bodies	Neither Trustworthy nor Untrustworthy	3	7	5	6	15	36
	Somewhat Trustworthy	8	39	20	49	65	181
	Somewhat Untrustworthy	0	2	3	0	10	15
	Very Trustworthy	11	31	12	29	11	94
	Very Untrustworthy	0	2	2	0	5	9
Total		22	81	42	84	106	335

Chi-Square Tests	Value	Df	Asymptotic Significance (2-sided)
Pearson Chi-Square	43.126[a]	16	.000
Likelihood Ratio	51.779	16	.000
N of Valid Cases	335		

a. 12 cells (48,0%) have expected count less than 5. The minimum expected count is ,59.

Cross-tabulation and Chi-Square results of trustworthiness of EU Regulatory Bodies and acceptance of Irradiation (1) Totally Acceptable (2) Somewhat Acceptable (3) Neither Acceptable nor unacceptable (4) Somewhat Unacceptable (5) Totally Unacceptable.

		Irradiated Foods					Total
		1	2	3	4	5	
EU Regulatory Bodies	Neither Trustworthy nor Untrustworthy	1	1	12	6	14	34
	Somewhat Trustworthy	3	27	53	40	54	177
	Somewhat Untrustworthy	0	3	4	0	6	13
	Very Trustworthy	7	18	34	22	9	90
	Very Untrustworthy	0	1	3	1	4	9
Total		11	50	106	69	87	323

Chi-Square Tests	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	33.543[a]	16	.006
Likelihood Ratio	39.910	16	.001
N of Valid Cases	323		

a. 12 cells (48,0%) have expected count less than 5. The minimum expected count is ,31.

Cross-tabulation and Chi-Square results of trustworthiness of EU Regulatory Bodies and acceptance of Nanotechnology (1) Totally Acceptable (2) Somewhat Acceptable (3) Neither Acceptable nor unacceptable (4) Somewhat Unacceptable (5) Totally Unacceptable.

		Nanotechnology					
		1	2	3	4	5	Total
EU Regulatory Bodies	Neither Trustworthy nor Untrustworthy	0	7	15	4	8	34
	Somewhat Trustworthy	7	35	62	35	38	177
	Somewhat Untrustworthy	0	3	3	2	5	13
	Very Trustworthy	9	24	38	15	4	90
	Very Untrustworthy	0	0	3	2	3	8
Total		16	69	121	58	58	322

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	29.792[a]	16	.019
Likelihood Ratio	36.052	16	.003
N of Valid Cases	322		

a. 12 cells (48,0%) have expected count less than 5. The minimum expected count is ,40.

Cross-tabulation and Chi-Square results of trustworthiness of EU Regulatory Bodies and acceptance of Thermal Emerging Novel Food Processing Technologies (1) Totally Acceptable (2) Somewhat Acceptable (3) Neither Acceptable nor unacceptable (4) Somewhat Unacceptable (5) Totally Unacceptable.

		Thermal Emerging Food Processing Technologies (Radio Frequency Heating and Ohmic Heating)					
		1	2	3	4	5	Total
EU Regulatory Bodies	Neither Trustworthy nor Untrustworthy	1	6	13	7	7	34
	Somewhat Trustworthy	10	33	70	36	28	177
	Somewhat Untrustworthy	0	1	5	1	7	14
	Very Trustworthy	18	12	40	15	5	90
	Very Untrustworthy	0	1	5	1	2	9
Total		29	53	133	60	49	324

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	40.360[a]	16	.001
Likelihood Ratio	37.900	16	.002
N of Valid Cases	324		

a. 10 cells (40,0%) have expected count less than 5. The minimum expected count is ,81.

Cross-tabulation and Chi-Square results of trustworthiness of EU Regulatory Bodies and acceptance of Non-Thermal Emerging Novel Food Processing Technologies (1) Totally Acceptable (2) Somewhat Acceptable (3) Neither Acceptable nor unacceptable (4) Somewhat Unacceptable (5) Totally Unacceptable.

		Non-Thermal Emerging Food Processing Technologies (Pulsed Electric Field (PEF), Ultrasound, High Pressure Processing (HPP))					
		1	2	3	4	5	Total
EU Regulatory Bodies	Neither Trustworthy nor Untrustworthy	3	3	16	6	6	34
	Somewhat Trustworthy	12	39	68	29	28	176
	Somewhat Untrustworthy	0	3	4	0	8	15
	Very Trustworthy	20	15	37	14	4	90
	Very Untrustworthy	1	2	2	1	3	9
Total		36	62	127	50	49	324

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	45.823[a]	16	.000
Likelihood Ratio	44.976	16	.000
N of Valid Cases	324		

a. 10 cells (40,0%) have expected count less than 5. The minimum expected count is 1,00.

Cross-tabulation and Chi-Square results of trustworthiness of academic researches and health professionals and acceptance of GMO (1) Totally Acceptable (2) Somewhat Acceptable (3) Neither Acceptable nor unacceptable (4) Somewhat Unacceptable (5) Totally Unacceptable.

		Genetically Modified Food (GMO)					
		1	2	3	4	5	Total
Academic Researches and Health Professionals		0	0	0	1	0	1
	Neither Trustworthy nor Untrustworthy	3	10	9	6	14	42
	Somewhat Trustworthy	7	44	18	52	62	183
	Somewhat Untrustworthy	0	0	2	1	10	13
	Very Trustworthy	12	26	11	24	19	92
	Very Untrustworthy	0	1	2	0	1	4
Total		22	81	42	84	106	335

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	41.869[a]	20	.003
Likelihood Ratio	42.578	20	.002
N of Valid Cases	335		

a. 16 cells (53,3%) have expected count less than 5. The minimum expected count is ,07.

Cross-tabulation and Chi-Square results of trustworthiness of academic researches and health professionals and acceptance of Irradiation (1) Totally Acceptable (2) Somewhat Acceptable (3) Neither Acceptable nor unacceptable (4) Somewhat Unacceptable (5) Totally Unacceptable.

		Irradiated Foods					
		1	2	3	4	5	Total
Academic Researches and Health Professionals		0	0	0	1	0	1
	Neither Trustworthy nor Untrustworthy	0	7	17	6	11	41
	Somewhat Trustworthy	5	20	54	52	46	177
	Somewhat Untrustworthy	0	1	3	2	7	13
	Very Trustworthy	6	22	30	8	21	87
	Very Untrustworthy	0	0	2	0	2	4
Total		11	50	106	69	87	323

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	37.467[a]	20	.010
Likelihood Ratio	39.264	20	.006
N of Valid Cases	323		

a. 17 cells (56,7%) have expected count less than 5. The minimum expected count is ,03.

Cross-tabulation and Chi-Square results of trustworthiness of academic researches and health professionals and acceptance of Nanotechnology (1) Totally Acceptable (2) Somewhat Acceptable (3) Neither Acceptable nor unacceptable (4) Somewhat Unacceptable (5) Totally Unacceptable.

		Nanotechnology					
		1	2	3	4	5	Total
Academic Researches and Health Professionals		0	0	0	1	0	1
	Neither Trustworthy nor Untrustworthy	0	9	23	2	8	42
	Somewhat Trustworthy	8	35	63	39	29	174
	Somewhat Untrustworthy	0	1	2	5	5	13
	Very Trustworthy	8	24	32	11	14	89
	Very Untrustworthy	0	0	1	0	2	3
Total		16	69	121	58	58	322

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	37.266[a]	20	.011
Likelihood Ratio	38.678	20	.007
N of Valid Cases	322		

a. 17 cells (56,7%) have expected count less than 5. The minimum expected count is ,05.

Cross-tabulation and Chi-Square results of trustworthiness of academic researches and health professionals and acceptance of Thermal Emerging Food Processing Technologies (1) Totally Acceptable (2) Somewhat Acceptable (3) Neither Acceptable nor unacceptable (4) Somewhat Unacceptable (5) Totally Unacceptable.

		Thermal Emerging Food Processing Technologies (Radio Frequency Heating and Ohmic Heating)					
		1	2	3	4	5	Total
Academic Researches and Health Professionals		0	0	0	1	0	1
	Neither Trustworthy nor Untrustworthy	1	7	23	4	7	42
	Somewhat Trustworthy	12	27	74	40	22	175
	Somewhat Untrustworthy	0	0	3	4	6	13
	Very Trustworthy	16	19	30	11	13	89
	Very Untrustworthy	0	0	3	0	1	4
Total		29	53	133	60	49	324

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	43.042[a]	20	.002
Likelihood Ratio	43.259	20	.002
N of Valid Cases	324		

a. 15 cells (50,0%) have expected count less than 5. The minimum expected count is ,09.

Cross-tabulation and Chi-Square results of trustworthiness of academic researches and health professionals and acceptance of Non-Thermal Emerging Food Processing Technologies (1) Totally Acceptable (2) Somewhat Acceptable (3) Neither Acceptable nor unacceptable (4) Somewhat Unacceptable (5) Totally Unacceptable.

		Non-Thermal Emerging Food Processing Technologies (Pulsed Electric Field (PEF), Ultrasound, High Pressure Processing (HPP))					
		1	2	3	4	5	Total
Academic Researches and Health Professionals		0	0	0	1	0	1
	Neither Trustworthy nor Untrustworthy	2	9	23	0	8	42
	Somewhat Trustworthy	14	33	71	36	20	174
	Somewhat Untrustworthy	0	1	3	4	6	14
	Very Trustworthy	19	19	29	8	14	89
	Very Untrustworthy	1	0	1	1	1	4
Total		36	62	127	50	49	324

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	49.459[a]	20	.000
Likelihood Ratio	52.904	20	.000
N of Valid Cases	324		

a. 15 cells (50,0%) have expected count less than 5. The minimum expected count is ,11.

Cross-tabulation and Chi-Square results of trustworthiness of private food companies and acceptance of GMO (1) Totally Acceptable (2) Somewhat Acceptable (3) Neither Acceptable nor unacceptable (4) Somewhat Unacceptable (5) Totally Unacceptable.

		Genetically Modified Food (GMO)					
		1	2	3	4	5	Total
Private Food Companies		1	0	0	0	0	1
	Neither Trustworthy Nor Untrustworthy	9	22	15	17	29	92
	Somewhat Trustworthy	2	31	12	21	19	85
	Somewhat Untrustworthy	6	20	5	35	34	100
	Very Trustworthy	2	1	1	0	1	5
	Very Untrustworthy	2	7	9	11	23	52
Total		22	81	42	84	106	335

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	54.985[a]	20	.000
Likelihood Ratio	44.175	20	.001
N of Valid Cases	335		

a. 11 cells (36,7%) have expected count less than 5. The minimum expected count is ,07.

Cross-tabulation and Chi-Square results of trustworthiness of private food companies and acceptance of Irradiation (1) Totally Acceptable (2) Somewhat Acceptable (3) Neither Acceptable nor unacceptable (4) Somewhat Unacceptable (5) Totally Unacceptable.

		Irradiated Foods					
		1	2	3	4	5	Total
Private Food Companies		0	1	0	0	0	1
	Neither Trustworthy Nor Untrustworthy	4	13	33	15	24	89
	Somewhat Trustworthy	5	18	29	15	15	82
	Somewhat Untrustworthy	2	10	27	28	30	97
	Very Trustworthy	0	1	2	1	1	5
	Very Untrustworthy	0	7	15	10	17	49
Total		11	50	106	69	87	323

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	23.279[a]	20	.275
Likelihood Ratio	23.101	20	.284
N of Valid Cases	323		

a. 14 cells (46,7%) have expected count less than 5. The minimum expected count is ,03.

Cross-tabulation and Chi-Square results of trustworthiness of private food companies and acceptance of Nanotechnology (1) Totally Acceptable (2) Somewhat Acceptable (3) Neither Acceptable nor unacceptable (4) Somewhat Unacceptable (5) Totally Unacceptable.

		Nanotechnology					
		1	2	3	4	5	Total
Private Food Companies		1	0	0	0	0	1
	Neither Trustworthy Nor Untrustworthy	3	14	39	13	18	87
	Somewhat Trustworthy	8	23	29	15	9	84
	Somewhat Untrustworthy	3	22	34	21	16	96
	Very Trustworthy	0	1	3	0	1	5
	Very Untrustworthy	1	9	16	9	14	49
Total		16	69	121	58	58	322

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	38.307[a]	20	.008
Likelihood Ratio	25.759	20	.174
N of Valid Cases	322		

a. 14 cells (46,7%) have expected count less than 5. The minimum expected count is ,05.

Cross-tabulation and Chi-Square results of trustworthiness of private food companies and acceptance of Thermal Emerging Food Processing Technologies (1) Totally Acceptable (2) Somewhat Acceptable (3) Neither Acceptable nor unacceptable (4) Somewhat Unacceptable (5) Totally Unacceptable.

		Thermal Emerging Food Processing Technologies (Radio Frequency Heating and Ohmic Heating)					
		1	2	3	4	5	Total
Private Food Companies		0	0	1	0	0	1
	Neither Trustworthy Nor Untrustworthy	10	14	37	15	13	89
	Somewhat Trustworthy	14	16	31	13	9	83
	Somewhat Untrustworthy	4	14	42	21	16	97
	Very Trustworthy	0	2	2	0	1	5
	Very Untrustworthy	1	7	20	11	10	49
Total		29	53	133	60	49	324

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	20.741[a]	20	.413
Likelihood Ratio	22.533	20	.312
N of Valid Cases	324		

a. 11 cells (36,7%) have expected count less than 5. The minimum expected count is ,09.

Cross-tabulation and Chi-Square results of trustworthiness of private food companies and acceptance of Non-Thermal Emerging Food Processing Technologies (1) Totally Acceptable (2) Somewhat Acceptable (3) Neither Acceptable nor unacceptable (4) Somewhat Unacceptable (5) Totally Unacceptable.

		Non-Thermal Emerging Food Processing Technologies (Pulsed Electric Field (PEF), Ultrasound, High Pressure Processing (HPP))					
		1	2	3	4	5	Total
Private Food Companies		0	0	1	0	0	1
	Neither Trustworthy Nor Untrustworthy	13	13	38	10	16	90
	Somewhat Trustworthy	13	22	27	12	8	82
	Somewhat Untrustworthy	6	15	42	19	14	96
	Very Trustworthy	1	1	2	0	1	5
	Very Untrustworthy	3	11	17	9	10	50
Total		36	62	127	50	49	324

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	20.131[a]	20	.450
Likelihood Ratio	21.525	20	.367
N of Valid Cases	324		

a. 10 cells (33,3%) have expected count less than 5. The minimum expected count is ,11.

Cross-tabulation and Chi-Square results of trustworthiness of media and acceptance of GMO (1) Totally Acceptable (2) Somewhat Acceptable (3) Neither Acceptable nor unacceptable (4) Somewhat Unacceptable (5) Totally Unacceptable.

		Genetically Modified Food (GMO)					
		1	2	3	4	5	Total
Media	Neither Trustworthy Nor Untrustworthy	5	28	19	32	38	122
	Somewhat Trustworthy	4	22	6	17	17	66
	Somewhat Untrustworthy	9	21	12	20	33	95
	Very Untrustworthy	4	10	5	15	18	52
Total		22	81	42	84	106	335

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	9.566[a]	12	.654
Likelihood Ratio	9.483	12	.661
N of Valid Cases	335		

a. 2 cells (10,0%) have expected count less than 5. The minimum expected count is 3,41.

Cross-tabulation and Chi-Square results of trustworthiness of media and acceptance of Irradiation (1) Totally Acceptable (2) Somewhat Acceptable (3) Neither Acceptable nor unacceptable (4) Somewhat Unacceptable (5) Totally Unacceptable.

		Irradiated Foods					
		1	2	3	4	5	Total
Media	Neither Trustworthy Nor Untrustworthy	2	12	45	23	34	116
	Somewhat Trustworthy	3	11	20	18	12	64
	Somewhat Untrustworthy	5	15	28	19	25	92
	Very Untrustworthy	1	12	13	9	16	51
Total		11	50	106	69	87	323

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	13.331[a]	12	.345
Likelihood Ratio	13.430	12	.339
N of Valid Cases	323		

a. 4 cells (20,0%) have expected count less than 5. The minimum expected count is 1,74.

Cross-tabulation and Chi-Square results of trustworthiness of media and acceptance of Nanotechnology (1) Totally Acceptable (2) Somewhat Acceptable (3) Neither Acceptable nor unacceptable (4) Somewhat Unacceptable (5) Totally Unacceptable.

		Nanotechnology					
		1	2	3	4	5	Total
Media	Neither Trustworthy Nor Untrustworthy	5	24	48	18	20	115
	Somewhat Trustworthy	5	14	21	16	8	64
	Somewhat Untrustworthy	4	15	39	17	18	93
	Very Untrustworthy	2	16	13	7	12	50
Total		16	69	121	58	58	322

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	13.062[a]	12	.365
Likelihood Ratio	12.788	12	.385
N of Valid Cases	322		

a. 3 cells (15,0%) have expected count less than 5. The minimum expected count is 2,48.

Cross-tabulation and Chi-Square results of trustworthiness of media and acceptance of Thermal Emerging Technologies (1) Totally Acceptable (2) Somewhat Acceptable (3) Neither Acceptable nor unacceptable (4) Somewhat Unacceptable (5) Totally Unacceptable.

		Thermal Emerging Food Processing Technologies (Radio Frequency Heating and Ohmic Heating)					
		1	2	3	4	5	Total
Media	Neither Trustworthy Nor Untrustworthy	8	19	57	17	16	117
	Somewhat Trustworthy	8	12	23	14	8	65
	Somewhat Untrustworthy	11	13	33	23	12	92
	Very Untrustworthy	2	9	20	6	13	50
Total		29	53	133	60	49	324

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	16.274[a]	12	.179
Likelihood Ratio	15.835	12	.199
N of Valid Cases	324		

a. 1 cells (5,0%) have expected count less than 5. The minimum expected count is 4,48.

Cross-tabulation and Chi-Square results of trustworthiness of media and acceptance of Non-Thermal Emerging Technologies (1) Totally Acceptable (2) Somewhat Acceptable (3) Neither Acceptable nor unacceptable (4) Somewhat Unacceptable (5) Totally Unacceptable.

		Non-Thermal Emerging Food Processing Technologies (Pulsed Electric Field (PEF), Ultrasound, High Pressure Processing (HPP))					
		1	2	3	4	5	Total
Media	Neither Trustworthy Nor Untrustworthy	8	19	57	16	17	117
	Somewhat Trustworthy	5	18	20	12	9	64
	Somewhat Untrustworthy	18	13	32	15	14	92
	Very Untrustworthy	5	12	18	7	9	51
Total		36	62	127	50	49	324

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	18.995[a]	12	.089
Likelihood Ratio	17.926	12	.118
N of Valid Cases	324		

a. 0 cells (,0%) have expected count less than 5. The minimum expected count is 5,67.